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HEAVY MINERAL ASSEMBLAGES OF SOME OF THE PLUTONIC ROCKS OF EASTERN OREGON[1]

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ABSTRACT

Plutonic igneous rocks constitute a large proportion of the pre-Tertiary terrane of the Blue Mountains of northeastern Oregon. Gabbro, hornblende-quartz diorite, biotite-quartz diorite, trondhjemite, and albite granite are abundant. The biotite-quartz diorite is notably less sheared than the other plutonic rocks and may belong to a later igneous cycle. On the other hand, it may belong to the same cycle as the other rocks and may be more massive because it was intruded near the close of the orogenic activity. Accordingly the correlation of the plutonic rocks is of major importance in the study of the regional geology.

The heavy residues of nineteen samples of plutonic rocks were examined by a method similar to that used by A. W. Groves for correlating some of the rocks of the Channel Islands.

The study has shown that the biotite-quartz diorite contains a suite of heavy minerals that is quite as diagnostic as the essential minerals. However, the heavy mineral suites of the more basic rocks are less trustworthy as a basis for classification, but if a number of slides of the heavy residue are studied it is generally possible to classify the rock. The fact that the distinction between the several suites is less definite than in the case of the biotite-quartz diorite may strengthen the field hypothesis of consanguinity of the gabbro, hornblende diorite, trondhjémite, and albite granite.

The fact that apatite is less abundant in the gabbro than in the diorite may mean that apatite does not always crystallize first, or that—because its crystals are usually small—the apatite is carried away from the larger separated crystals of augite and plagioclase by movements of the rest-magma.

The zircon and apatite crystals of the hornblende-quartz diorite and trondhjemite commonly appear to be corroded. This fact gives some reason to question the commonly accepted idea that these minerals, because they are among the first to crystallize, are stable throughout the later magmatic history.

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INTRODUCTION

Plutonic igneous rocks make up a large part of the pre-Tertiary terrane of the Blue Mountains of eastern Oregon. (See fig. 1.) The plutonic rocks recognized include gabbro with subordinate norite, peridotite, pyroxenite, and serpentine; basic diorite, hornblende-quartz diorite, biotite-quartz diorite, trondhjemite, and albite granite. Field work by the writers and their associates in the Baker City quadrangle and nearby areas in 1929 and 1930 resulted in the tentative assignment of these intrusive rocks to two igneous cycles, the earlier represented by the gabbro, norite, and other basic rocks, hornblende-quartz diorite, trondhjemite, and albite granite, the later by the biotite-quartz diorite and associated dikes. The principal criterion used in this division was structural, the rocks assigned to the earlier cycle being notably more sheared and even gneissic, while the biotite-quartz diorite shows only a faint mineral parallelism developed near the borders of the different masses. However, the fact that the schistosity of the country rock tends to follow the periphery of some of these biotite-quartz diorite masses seems to render this structural criterion of somewhat less value, as the biotite-quartz diorite might belong to the same magmatic cycle as the other rocks and owe its more massive structure to its intrusion almost at the close of the orogenic activity. Under this hypothesis, it would follow that even though the forcible intrusion of the biotite-quartz diorite masses may have induced peripheral schistosity in the country rocks, its final consolidation occurred under static conditions so that only the border facies show marked mineral parallelism.

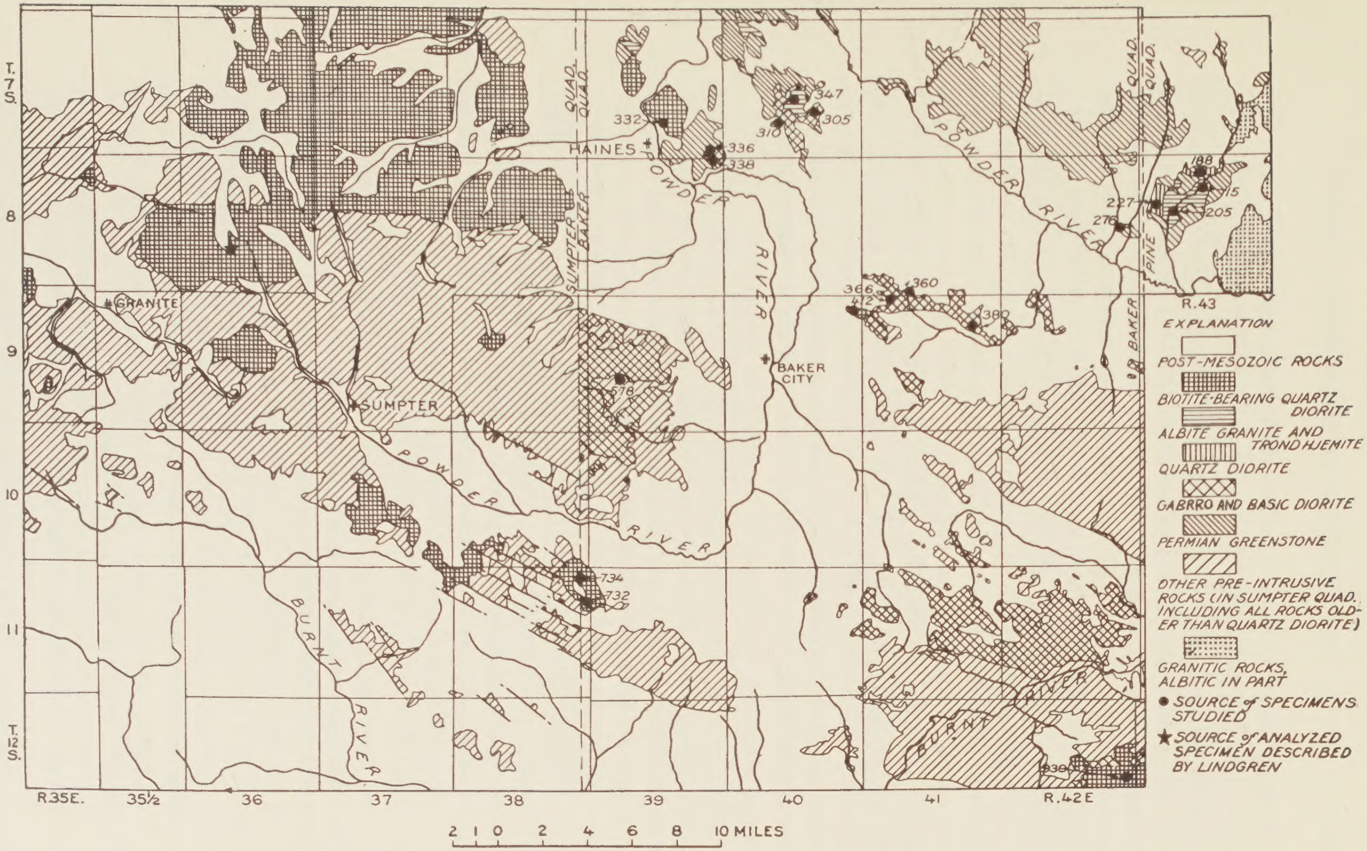

FIG. 1. Generalized geologic map of the Sumpter, Baker City, and part of the Pine quadrangles.
Geology of the Sumpter Quadrangle by J. T. Pardee and D. F. Hewett, Baker Quadrangle by James Gilluly, J. C. Reed, C. F. Park, Jr., and R. E. Stewart.

Independent evidence for the existence of more than one magmatic cycle in the region is supplied by the presence of volcanic rocks in the representatives of the Mississippian (?), Permian, and Triassic in the Blue Mountains, and by the fact that some at least of the intrusive rocks cut the Triassic. Correlation of the earlier plutonic rocks with any of these surficial lavas has not yet proved feasible however, if indeed, any of the plutonic rocks now exposed are so related. Accordingly the problem of correlation of the plutonic rocks assumes major proportions in a study of the regional geology. Presumably, detailed areal studies of more of the area will throw much light on the matter; pending these, however, it seems desirable to attack the problem as thoroughly as is permitted by the evidence at hand. In this connection our attention was drawn to the recent work of Groves[2] on the correlation of plutonic rocks by means of the suites of heavy minerals they contain and it was decided to see what light a study of these minerals would throw upon the correlation of the rocks in question.

ABSTRACT OF GROVES' WORK. Groves worked with specimens between a quarter of a pound and one and one-half pounds in weight. These he prepared as follows: The specimen was crushed in a mortar, taking precautions to minimize the formation of rock dust. After the powder was passed through a thirty mesh sieve it was washed, dried, and then separated by means of bromoform. The heavy residues of those specimens yielding large quantities of biotite were subjected to special treatment. They were divided into two parts, one of which was boiled in concentrated hydrochloric acid (baueritized) to leach the mica so it could be removed, and the other retained to study the minerals destroyed by the acid in the first part. The heavy residues in which hornblende was plentiful were passed under an electro-magnet. Some residues were further separated with methylene iodide.

In Groves' later paper[3] he makes certain claims for, and points out certain limitations of the method. He also answers several criticisms which have been made regarding it. The following quotations present some of his main points.

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[2] Groves, A. W., The heavy minerals of the plutonic rocks of the Channel Islands: *Geol. Mag.*, vol. **LXIV**, pp. 241–51 and 457–73, 1927.

The heavy mineral suites and correlation of the granites of Northern Brittany, the Channel Islands, and the Cotentin: *Geol. Mag.*, vol. **LXVII**, pp. 218–240, 1930.

[3] The heavy mineral suites and correlation of the granites of Northern Brittany, the Channel Islands, and the Cotentin: *Geol. Mag.*, vol. **LXVII**, pp. 224–239, 1930.

The basic idea which prompted this work has been as follows:—Neighboring granites, if comagmatic, should reflect their relationship in possessing heavy mineral suites with many points in common and this for the reason that such minerals as zircon, apatite, monazite, rutile, iron ore, and sphene, generally crystallize from the magma at an early stage of cooling and thus, in their colour, inclusions, habits and peculiarities, give valuable characteristics dependent on the original composition and early cooling history of the magma. . . .

Merely to enumerate the minerals present and to attempt correlation by means of the names of the mineral species is as futile as to attempt accurate stratigraphical zonal correlation when the generic names only of the fossils involved are known. The colour, dimensions, habits, nature of inclusions and any other peculiarities of each mineral have to be carefully noted and compared with those in other specimens. . . .

Attention should be focussed principally on the primary stable minerals such as zircon, apatite, monazite, rutile, sphene, muscovite, biotite, hornblende, iron ores, etc. Next in importance came the pneumatolytic minerals such as tourmaline, fluor, topaz, cassiterite, etc. . . .

Less attention need be paid to minerals of the epidote and chlorite groups, these being mostly secondary. Orthite is however an exception, as it indicates the presence of cerium in the magma. . . .

The index figure or percentage weight of the rock exceeding bromoform in density (about 2.8) should be determined in the case of every sample. It is useful for comparison and in this way differentiation and contamination by assimilation are readily detected—even when the worker has not visited the outcrop in the field. . . .

Upon theoretical grounds various objections to the method have been raised, among which the following are perhaps the most important:

(1) The heavy minerals of a granite are dependent not only on the original composition of the magma itself, but also on the rocks into which it is intruded.

(2) The habits and characters of minerals such as zircon, etc., are known to be dependent on the physical and chemical environment at the time of crystallization. Big differences in habit might therefore be expected between a zircon which crystallized near the roof and another in much greater depth.

(3) Why bother with the heavy and accessory minerals at all: are not the characters of the essential minerals more important? . . .

The questions raised are answered in the following paragraphs. . . .

(1) . . . If intrusion is accomplished entirely by stopping and assimilation then the heavy mineral suite must depend as much on the nature of the country rocks as on the original composition of the magma. . . . That assimilation of country rocks has taken place is acknowledged but this appears to be merely that which might be expected by reason of the excess of heat possessed by the magma after it had come into position. . . . Therefore, the heavy minerals of the normal uncontaminated granite give a very fair representation of the content of minor constituents in the original magma irrespective of the nature of the country rock. . . . Numerous specially selected specimens have been examined to test the effects of contamination and these have been found to be as follows:

(a) The zircons of the assimilated rock in some cases appear to survive as xenocrysts.

(b) Where granite is intrusive into gabbro it may contain hornblende. . . .

(c) Assimilation of argillaceous sediments increases the production of biotite and sphene in most cases . . . . Andalusite appears to demand special conditions for its formation. . . .

(2) Dr. A. Brammall has informed the writer that in the case of the Dartmoor granite there is some slight difference in habit between the zircons of the highest and lowest types of granite exposed. It is already quite clear, however, that this is not a serious factor; nevertheless it should not be entirely overlooked.

(3) The importance of the essential minerals is in no way belittled. The heavy minerals, however, reflect the presence of the minor constituents, which, for correlation purposes, are quite as important as the major constituents. Moreover, the heavy minerals serve as an important index to the early cooling history. . . .

METHOD OF PROCEDURE

We adopted the method of Groves to free the accessory minerals, but owing to finer grain of our rocks, used smaller screens. The best material was that which passed a 100 mesh and was retained by a 200 mesh screen. The only heavy liquid used in our work was bromoform, sp. gr. 2.84. The biotite-rich residues were baueritized for ease of study.

The residues were passed under a horse-shoe magnet. The only minerals removed in this way were magnetite and pyrrhotite. Following the suggestion of Rastall and Wilcockson,[4] the magnetic separate of each specimen was treated with a few drops of water in a watch glass for several hours. Pyrrhotite is completely decomposed by this treatment while magnetite is unaltered and the two minerals are by this method readily discriminated. The non-magnetic residue was examined under a binocular to distinguish ilmenite and pyrite. The non-opaque minerals were examined by the usual immersion methods.

DETERMINATION OF THE INDEX FIGURE

Groves terms the amount of heavy mineral in a sample expressed as weight per cent of the total sample the "*index figure.*" In this paper the term, although subject to objection, is retained.

The index figure was determined by weighing the light fraction and the heavy fraction of a sample and calculating the weight per cent of the heavy fraction. Several of the sized samples were weighed before separation and the results compared with the sums of the weights of the heavy and the light fractions. The loss was found to be negligible, less than 2 per cent.

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[4] Rastall, R. H., and Wilcockson, W. H., The accessory minerals of the granitic rocks of the English Lake District: *Quart. Jour. Geol. Soc. London*, vol. **71**, p. 617, 1915.

A consideration of the methods employed shows that the recorded index figure commonly differs considerably from the true index figure which would be almost impossible to determine with great accuracy. Despite care in crushing we never succeeded in effecting clean separations of the entire rocks into individual grains.

In most separations there is an intermediate zone in the funnel between the heavy and light fractions in which are suspended particles of nearly the same density as the separating medium and of particles made up of two or more minerals whose average density is about the same as the medium. It is often a question just where to draw the dividing line between heavy and light fractions.

These difficulties depend in large part on the grain size of the rock and the relative grain sizes of the heavy and light minerals. For instance, the feldspars of one of the border facies examined contain myriads of minute sillimanite fibers which could not be freed except by crushing to a degree that would entail great difficulties in making gravity separations.

In brief: The finer the sample the more difficult the gravity separation. The finer the sample the more complete division into particles consisting of a single mineral. The finer the sample, after a certain point, the greater breakage of the small crystals used in crystallographic study.

Chemical analyses were available for three of the specimens, 188, 205, and 15. The modal mineral compositions were caluculated for these specimens from their analyses on the basis of the microscopic study of the rocks, and their theoretical index figures were in this way, found to be 36, 24, and 8, respectively. The corresponding indices as measured were 32, 8, and 1. These figures clearly show that the index figures obtained in our work are very crude and of little value in classifying the rocks.

EXAMINATION OF THE RESIDUES

At least half a dozen mounts were made from each sample and in many instances several times that number. Figure 2 shows how the results were tabulated so as to indicate the presence or absence of a particular mineral in a sample, the relative amount of a mineral in the heavy residue, and the index figure. The spaces indicating mineral frequencies are to be read in fifths, corresponding to the following order of abundance: very rare, rare, common, very common, abundant.

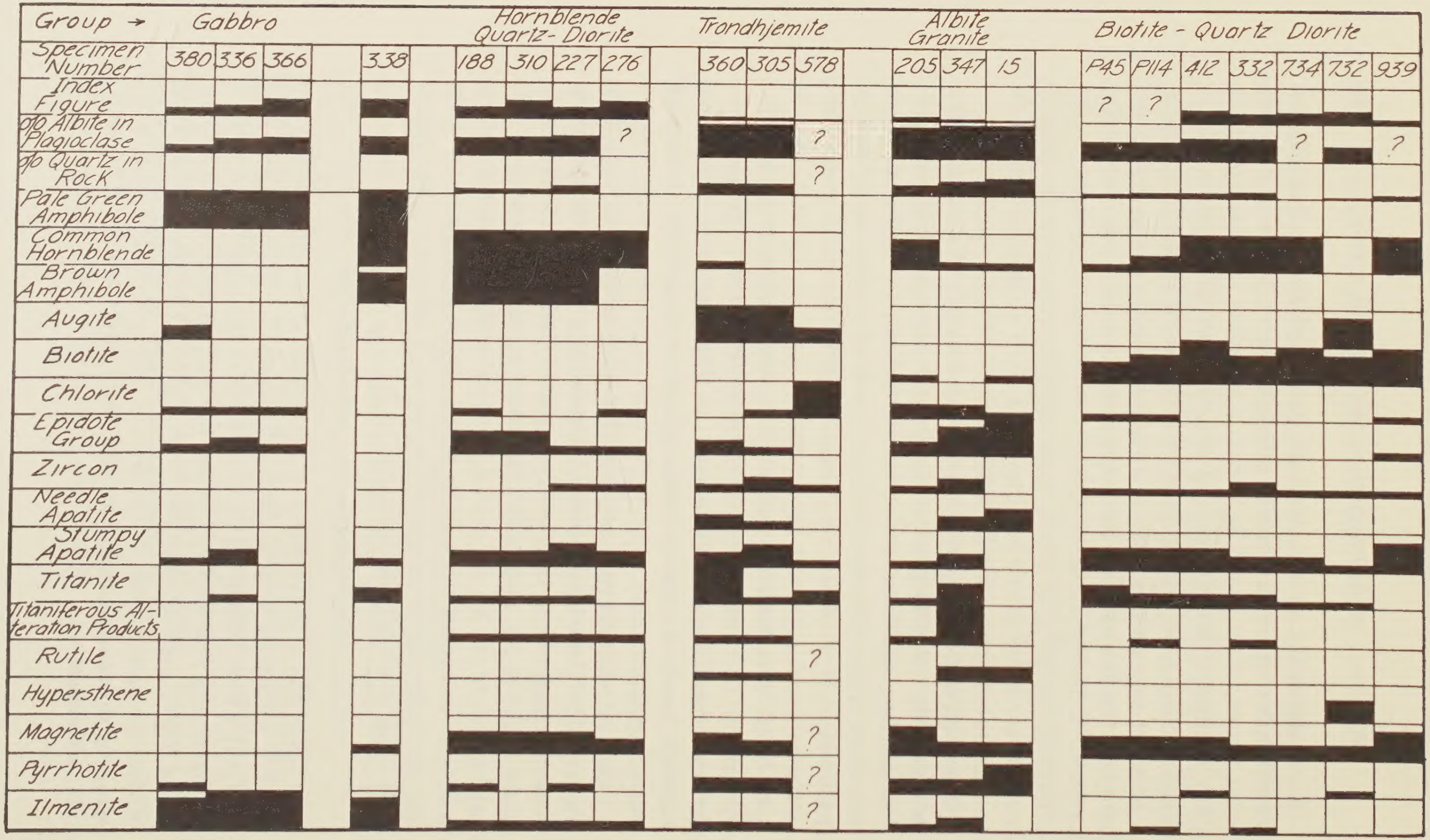

FIG. 2. Mineral frequencies in heavy residues of rock suites studied. Data for columns shown under P45 and P114 and all feldspar determinations and quartz percentages based on thin section studies.

No attempt was made to identify and count all the grains in any particular mount or even field; the figures representing relative quantities are estimates only.

More important than the above criteria for grouping rocks together are the varietal characters[5] of some of the heavy accessories.

The dimensions of typical minerals were taken. The proportions, such as the ratio of length to breadth, appear to be more important, however. In many of the crops of heavy minerals such measurements can be made on the smaller accessories only, as the dimensions of the larger ones have been destroyed during crushing.

The color and the presence or absence of inclusions was noted. Where present the identity, number, arrangement, and other peculiarities of the inclusions seem to be characteristic of the individual rock bodies.

The bounding surfaces of a mineral are among the most important features. A mineral may be bounded by fracture surfaces, cleavage planes, crystal faces, corrosion surfaces, or any combination of these. If bounded by crystal faces, the typical habits of crystals of the mineral in a sample were observed. Corrosion obscures the habits of some minerals, sometimes obliterating small faces, but the degree of corrosion seems of itself to be characteristic.

Biotite-quartz Diorite

The residues of several samples (numbers 332, 412, 734, and 939) of the biotite-bearing quartz diorite were studied. These were from widely separated localities as shown in figure 1. In addition the residues of a rock believed to present a finer grained border facies of the quartz diorite, number 732, and thin sections of all these together with two other specimens were studied. No examination was made of the residues of any of the numerous darker segregations in the quartz diorite.

Lindgren[6] gives an analysis made by Dr. W. F. Hillebrand of a "granodiorite" from the northern base of Bald Mountain (Sumpter quadrangle). Study of thin sections of the rock from which the analyzed specimen was taken shows that it is undoubtedly similar to the masses from which the four samples we examined were collected. The theoretical index figure of the rock as calculated from the norm given in Washington's Tables, page 257, is 7.00. The index figures of the rocks crushed varied from 11 to 31, the border facies, No. 732, reaching 34.

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[5] The use of the term "varietal characters" is continued in this paper following Groves' usage. It is not used in the sense alone of the characters defining a particular variety of a mineral group such as the amphiboles, but includes all the characters that are observed that may help to distinguish one mineral from a corresponding mineral from a different sample.

[6] Lindgren, Waldemar; The gold belt of the Blue Mountains of Oregon: *U. S. Geol. Survey*, Twenty-second Ann. Rept., pt. 2, p. 587, 1900–1901.

The following paragraphs list the minerals seen in the residues and describe their varietal characters.

Hypersthene. Hypersthene, pleochroic in light green and light red, was found only in sample 732, in association with augite.

Titanite. Titanite occurs in small amounts in all specimens except 939. It was seen only as fracture fragments.

Magnetite. Magnetite occurs more or less abundantly in all the samples. It was most often seen as irregular black splotches from a few hundredths to a few tenths of a mm. across. In most samples a few grains were seen showing crystal outlines. This was particularly true of sample 939.

Sillimanite. The determination of sillimanite was doubtful. It was seen only in number 732, a specimen selected as representing a contact facies and which gives evidence of endomorphism in its contained hypersthene. It occurs as very fine needles impregnating feldspar crystals. The needles were all too fine to permit accurate determination of the optical properties.

Zircon. Zircon has been detected in all the samples. It commonly, but not exclusively, occurs in the biotite, where it is surrounded by moderately intense pleochroic halos. The lengths of the crystals usually fall within the limits. .03 mm. and .15 mm. while the thicknesses lie typically somewhere between .01 mm. and .06 mm.

The zircons are always euhedral and doubly terminated except when broken. No sign of corrosion was seen except in specimen 332 where one zircon is slightly corroded.

Plate I shows several typical crystals. The first and the second order prisms or the ditetragonal prism were present on all the crystals examined. The corresponding pyramid faces were also developed and in many crystals a myriad of faces may be made out, notably on some of the crystals of specimen 939. All of the crystals seen were clear and colorless. A few rounded indeterminable inclusions, probably gas or liquid filled cavities, were noticed in a few crystals.

Apatite. Apatite, like zircon, was definitely established in all samples.

Two varieties of apatite crystals have been distinguished, a long slender variety, and a much stouter variety.

The slender apatites range in length from .05 mm. to .03 mm., and in thickness from .015 mm. to .008 mm. The apatites of the stout variety are of much greater average size ranging in length between .20 mm. and .10 mm. and in width between .18 mm. and .08 mm.

Typical apatites of the stout variety have been represented in Plate I. The crystals are characteristically developed with sharp edges. Exceptional ones are slightly corroded. The crystals are as a rule simple, consisting of combinations of the prism, pyramid, and base. In many crystals the base is not conspicuously developed

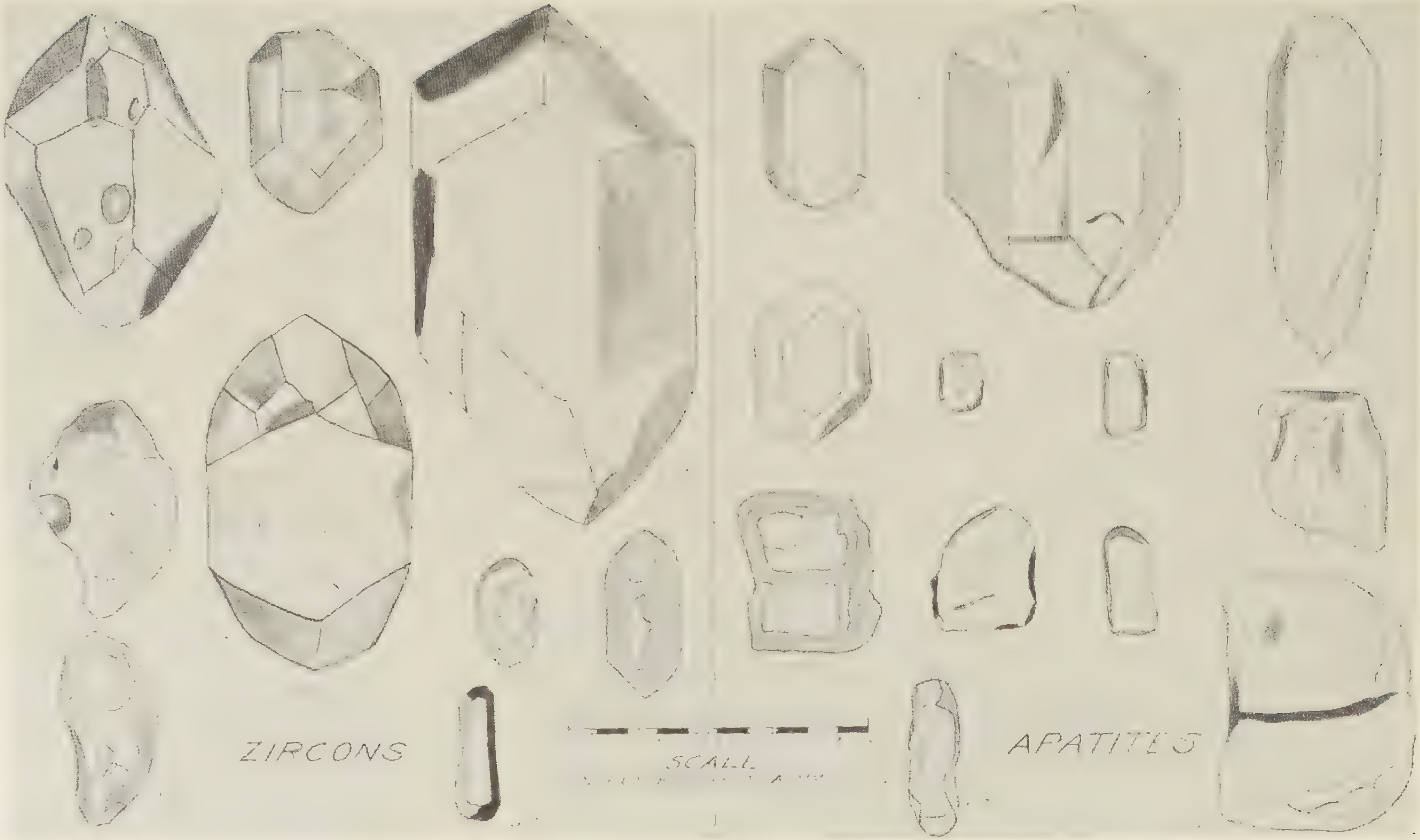

Plate I. Zircons and apatites. Reference to figure 2 will show in what group various individuals belong.

probably because of breakage in crushing, but at least as many are doubly terminated.

The crystals are clear and colorless with few exceptions. Small inclusions, which appear reddish under high powers and are probably gas cavities, are nearly always present.

The foregoing features conform to the hypothesis, based upon field studies and examination of thin sections, that all the specimens examined in this set are closely related and probably represent intrusive masses which may be directly correlated and which may be continuous in depth.

The megascopically observable heavy minerals appear to be identical in all the specimens.

Sillimanite and hypersthene are present in the border sample only and are not considered as furnishing criteria of correlation. Neither is augite, which, though vestigial, altering to hornblende in No. 412, is an essential mineral only in the same border specimen.

Small significance is attached to the titanite, which, although seen in all the samples, is present in other plutonic rocks of eastern Oregon in apparently identical grains.

Magnetite is common in all the plutonic rocks of eastern Oregon and it therefore furnishes no criteria. This suite is notably lower in pyrrhotite and ilmenite than any of the other suites collected.

Zircon and apatite are the two heavy minerals whose presence, relative amounts, and varietal characters are considered the most characteristic. Zircon is always subordinate to apatite.

The Gabbro, Hornblende-quartz Diorite, Albite Granite Series

Inasmuch as one of the objects of this paper is to test the postulated consanguineous nature of the great series of intrusions occurring in eastern Oregon and ranging from gabbro to quartz diorite and trondhjemite, and from quartz diorite to albite granite as proposed by one of the authors,[7] the residues of fourteen members of the series have been examined. Figure 1 shows the sources of the samples. Thin sections of most of the specimens were available as were three chemical analyses.

Study of thin sections and of the residues resulted in the collection of the samples into four groups: the gabbros, the hornblende-quartz diorites, the trondhjemites, and the albite granites.

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[7] Gilluly, James, Origin of the albite granite near Sparta, Oregon: *U. S. Geol. Survey Prof. Paper* 175-C, (in preparation).

GABBRO. Four specimens were selected as representing the gabbro, numbers 338, 366, 336, 380. The textures are widely divergent. Number 336 is exceedingly coarse grained with hornblende crystals up to 1.5 cm. in length. The feldspar crystals are also large, up to .5 cm. across. Number 380 is a dark colored specimen. Its texture is also coarse with hornblende and feldspar crystals having dimensions of several millimeters. Number 338 is medium grained while 366 is fine grained and bounded by chlorite-covered joint planes. Thin section studies show that specimen 338 has a calcic andesine and a little quartz, and probably should be classed with the hornblende-quartz diorites. As will be noted in the table, its heavy mineral assemblage is intermediate between the two groups. It will, however, be discussed with the gabbro group.

The index figures as determined range from 23 to 53. Two determinations were made on each sample but on material crushed to different grain size. Estimates of the volume percentages of the various minerals in specimens 338, and 336 were made from thin sections. A recalculation of the results to weight percents gives theoretical index figures of 57 and 41 respectively, contrasting with the weighed figures of 53. and 28. Varietal characters of the minerals are as follows:

Ilmenite. The relative proportions of ilmenite in the residues differ only slightly. It occurs as irregular or rounded opaque blebs or as fragments having sharp edges some of which appear to be crystal boundaries. In size they range from very minute to .1 mm. across.

Magnetite. Magnetite is present in small amounts in No. 338 which thereby shows similarity to the hornblende-quartz diorites.

Among the alteration minerals, chlorite, zoisite and epidote occur. They are not considered diagnostic.

The heavy mineral residues of the four specimens have the following characters in common: (1) The most conspicuous mineral in the residues is a light green amphibole not here described, seen in the residues of no other rocks of the region. (2) Zircon was not seen in any of the residues. (3) The dominant opaque mineral they contain is ilmenite. (4) They contain little apatite and such as they do have is badly corroded.

HORNBLENDE-QUARTZ DIORITE. The residues of four specimens of hornblende-quartz diorite were studied, numbers 310, 276, 188, and 227. Specimen 338, described with the gabbros, also has some characters in common with these.

Number 310 is a greenish gray, medium grained, equigranular rock, in which hornblende and plagioclase are visible to the unaided eye. The specimen is veined with calcite.

Number 276 is a dark colored, gneissic rock. The ground mass is fine grained but phenocrysts of hornblende and plagioclase are numerous.

Specimen No. 188 is grayish, coarse grained, and exhibits macroscopically hornblende, feldspar, and quartz.

Number 227 is similar to 188 but is darker, more altered, and does not show as much quartz.

The determined index figures of the four specimens is as follows: number 310, 51; number 276, 51; number 188, 32; and number 277, 31.

Thin section estimates of volume per cents of the various minerals recalculated to weight per cents gives theoretical index figures of 57 for number 310 and 36 for number 188.

The heavy minerals found and their varietal characters are as follows:

Magnetite. Magnetite occurs as inclusions in hornblende and as liberated fragments and rounded irregular masses usually of small dimensions.

Apatite. Apatite is rare in all specimens but 227 in which it is common. Plate I shows typical apatites of this group. Most of the apatites of 310 are small, slender, broken, and corroded prisms, averaging about .05 mm. long and .016 mm. in thickness. However, some larger ones .3 mm. long and .2 thick also occur.

The typical apatites of 188 are somewhat thicker. All of them are corroded but a few show indications of the terminating pyramid. They range in dimensions up to .4 mm. in length by .1 mm. in thickness. Some of the thin prisms like those in 310 were also seen in 188. Most of the crystals show very few inclusions but some are dark in patches and cloudy throughout.

In addition to the types seen in 310 and 188 there occur in specimen 227 small apatite crystals (about .04 mm. by .02 mm.) having a fairly sharp crystal outline.

Zircon. Zircon is very rare in 227 and 276. The few grains seen were small and corroded and showed no crystal terminations. None were found in the other specimens.

Neglecting the nearly ubiquitous and presumably insignificant epidote, chlorite, and leucoxene, the hornblende-quartz diorites are characterized by the presence of apatite, magnetite, and ilmenite in all and of small amounts of zircon and pyrrhotite in some specimens.

Contrasted with the gabbro suite, these rocks show relatively more apatite and much magnetite; contrasted with the biotite-quartz diorite, they show no biotite, relatively less apatite, which is, however, in larger crystals and much more corroded, less zircon which is also more corroded, and more ilmenite.

TRONDHJEMITE. Three specimens, Nos. 360, 305, and 578 were, because of their dominant sodic oligoclase feldspars, classed as trondhjemites (oligoclase-quartz diorite). From field studies they were regarded as belonging to the hornblende-quartz diorite suite but are distinguished from these rocks in several respects.

All are very light colored medium grained rocks, highly quartzose, with macroscopic plagioclase and few mafic minerals. Their index figures were all determined as less than 5.

Varietal characters of the accessory minerals are as follows:

Zircon. All the specimens carry zircon, ranging between .04 mm. and .10 mm. in length and .015 and .03 mm. in thickness. They are barrel-shaped, free from inclusions and notably corroded.

Apatite. Two varieties of apatite are present, one needle-like, the other stumpy. The needle-like variety ranges between .04 and .20 mm. in length and from .003 to .006 mm. in thickness. The stumpy apatite is about .30 mm. long and .15 mm. thick. Both varieties are notably corroded.

Titanite, although especially prominent in specimen 360 is poorly formed, and shows corroded outlines. None of the entire suite of specimens examined shows titanite whose characters were recognized as distinctive, however.

Rutile. This suite of specimens is the first included in our study in which rutile is present. It is in notable association with quartz, in which it occurs as very elongate, fine needles.

Magnetite and pyrrhotite are about equally conspicuous in the two specimens examined. This marks a notable relative increase in the pyrrhotite over its proportion in the quartz diorites. Ilmenite is present, but not abundant, in all the specimens.

The heavy mineral suites of the trondhjemite specimens are distinguished by the presence of augite (which is noteworthy in rock so silicic), two varieties of apatite, rutile, zircon, magnetite, pyrrhotite, and ilmenite, as well as the almost ubiquitous chlorite, epidote, titanite, and leucoxene. Common hornblende is a very minor constituent and biotite is lacking. The suite shows relationships with that of the albite granites, next to be described, in the presence of "needle" apatites, rutilated quartz, and considerable pyrrhotite along with magnetite. It shows relationships with the hornblende-quartz diorite suite in the common presence of corroded apatite and zircon crystals of similar proportions, except that the "needle" apatites do not occur in the diorites.

The suite is also distinguished by the relatively very low index figures, from all but the albite granites.

ALBITE GRANITE. The specimens representing the albite granite group are all light gray or slightly iron stained. They are medium grained with macroscopic quartz, plagioclase, and a little dark mineral. All have the appearance of altered rocks. The index figures of all are less than 10.

The heavy minerals found are as follows:

Magnetite. This mineral is common in all the residues of this group. It appears most frequently as irregular blebs and blotches from very small to several tenths of a mm. across. Much of the magnetite occurs as inclusions in chlorite or augite and some is even included in apatite crystals.

Ilmenite. Although more abundant in this suite than in the biotite-quartz diorites, ilmenite is not an important accessory in the albite granites.

Pyrrhotite. This suite of rocks is characterized by a very much higher proportion of pyrrhotite relative to the other opaque minerals than any of the other rocks except the trondhjemites. It is present in each of the albite granites and in No. 15 is more abundant than magnetite.

Apatite. Although apatite is present in each residue its proportions have a considerable range.

The apatite crystals are all much corroded. Usually the elongation is still parallel to the axis but seldom do any of the pyramidal terminations remain. In spite of the degree of corrosion the apatites appear to fall into two groups according to size and shape.

Epidote. Although not present in every specimen, epidote is, on the whole, far more abundant in this suite than in any other.

Zircon. Zircon is not conspicuous in this suite of rocks, although it was detected in all except No. 15. Most crystals are small, the dimensions of an average crystal being about .01 mm. by .004 mm.

The zircons are either clear and colorless or very slightly yellow. Zircon crystals are commonly included in chlorite.

Titanite. Titanite is plentiful in the residues of No. 347 but is absent from those of No. 15. It occurs in the residues in broken grains. The thin sections show the typical acute rhombic shape.

All the members of this group have determined index figures below 10.

Zircon was observed in two of the three specimens. The mineral is corroded, as in the hornblende diorites and trondhjemites. Apatites of this group, like those of the trondhjemites, fall into two groups. This suite also resembles the trondhjemites in the possession of rutilated quartz and much pyrrhotite. It carries no pyroxene, however, and does have a little biotite.

Specimen 205, although classed with the albite granites, is interpreted from other evidence[8] as a product of partial albitization of the hornblende-quartz diorite. It will be observed that the heavy mineral assemblage of this specimen shows characters intermediate between the diorite and the albite granites, perhaps resembling those of the diorites somewhat more than those of the granites. In this connection it is considered significant that the corrosion of the zircon and apatite mildly shown by the hornblende diorites is very conspicuous in this specimen and is extreme in the albite granites, a result which might be expected if the albitization hypothesis is sound.

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[8] Gilluly, James, The origin of the albite granite near Sparta, Oregon: *U. S. Geol. Survey Prof. Paper* 175-C, (in preparation).

Summary and Discussion

The heavy residues of nineteen samples of plutonic rocks from eastern Oregon were examined following in general the method used by A. W. Groves for similar work in the Channel Islands. Xenotime, monazite, brookite, and anatase, commonly occurring as accessories in other granitic rocks were searched for but not found.

The study has shown that the biotite-quartz diorites represented by specimens collected over an area about thirty miles long are characterized by accessory minerals whose similarities are as striking as those of the essential minerals. The apatites and zircons in particular have similar development in size, proportions, and degree of perfection of crystal forms. The similarities are so marked that a single mount of the residues almost suffices to place the specimen in or out of this group. Exception to this rule is found in the one contaminated rock examined. In this specimen the similarities with others of the group are very tenuous and in default of field evidence would by no means enable the rock to be placed with confidence. However, the same criticism could be made against a classification based solely on study of the essential minerals, for these, too, are aberrant in this specimen.

In the other, more basic rocks the heavy mineral suites give less ground for confident classification, although we believe it possible to determine from study of a number of slides of a residue in what group the rock should be placed. Perhaps the very fact that the distinction between the several suites is less definite is some ground for additional confidence in the field hypothesis of consanguinity of these rocks.

Nevertheless there are differences in the accessory minerals of these rocks such that the residues alone are hardly a safe basis for correlating them. For instance one of the gabbro specimens contains neither titanite nor apatite (or at least diligent search failed to reveal any), yet apatite is present in all the other rocks, and titanite was found in all but two others. To the writers, this and smaller differences of the same kind found in other rocks of the suite examined are not grounds for postulating different intensities of foliation the rocks have undergone, yet the accessories of the cataclastic diorites are not broken and it is difficult to see how crushing could eliminate them completely from any rock. More probable causes are assimilation or differences in the depth beneath the roof of the intrusive.

The fact that apatite is less abundant in the gabbros than in the diorites, a feature that the average analyses of Daly[9] shows in general, may indicate that this mineral either does not always crystallize first,[10] or that due to the usual small size of its crystals it is carried off by movements of the rest-magma with respect to the larger separated crystals of augite and plagioclase. In either case it loses much value as a diagnostic mineral in the correlation of the more basic rocks. Zircon is useless in the same rocks. Of course, Groves has never urged the application of the method to these rocks, but if the implicit postulate underlying Groves' work is sound, that is that magmas of a given age have characteristic chemical peculiarities which are necessarily reflected in the mineralogic peculiarities. such idiosyncrasies should be recognizable in the parental gabbros as well as in the granites. Indeed, as Wells[11] has pointed out, such characteristics in so far as they are original, should be less subject to masking by contamination in the gabbros than in the granites.

Wells' criticism appears to be, in the main, well-founded. In summary, he points out that, even assuming a common composition for parental magma of a given age, many factors affect the total composition of satellitic magma bodies. Among these are contamination, depth of cover and consequent effects upon volatile content, and structural history involving such matters as sinking of minerals under gravity and filter pressing. Consequent upon such factors it is a priori unlikely that all granites of a given age, even in the same orogenic zone, would yield identical heavy mineral suites. Accordingly, most of the accessories are more apt to reflect differences in intrusive history than in original magmatic composition. On this basis he excludes such minerals as tourmaline, fluorite, topaz, cassiterite, and much rutile, anatase, and brookite, which are likely to be variable due to volatile content, and hence to vary with depth in one and the same granite mass. Cordierite, silimanite, andalusite, spinel, and garnet are excluded by Wells because they are very likely to be contamination products, while chlorite, serpentine, and epidote, reflecting hydrothermal processes, are likewise rejected as insignificant. Accordingly Wells regards only zircon, monazite, and apatite as likely to reflect original characters of the magma, and only very striking differences in these minerals are justifiably used as a basis of correlation.

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[9] Daly, R. A., Igneous rocks and their origin: pp. 19–36, *New York*, **1914.**

[10] Apatite is clearly enriched in the late magmatic or hydrothermal stage in many rocks in the Ardnamurchan volcanic center. See Thomas, H. H., in *Geol. Survey Scotland Ardnamurchan Memoir*, pp. 147, 227, 306 and many others. See also Gillson, J. L., Contact metamorphism of the rocks in the Pend Oreille district, northern Idaho: *U. S. Geol. Survey Prof. Paper* **158-F,** pp. 118–119, 1929.

[11] Wells, A. K., The heavy mineral correlation of intrusive igneous rocks: *Geol. Mag.*, vol. **68,** pp. 255–262, 1931.

Wells' comments seem to us somewhat too pessimistic. It is no doubt true that structural influences on the mineral characters may be expected to be great. To the writers this seems a much more cogent reason for anticipating recognizable mineralogic peculiarities of age significance than the unproved assumption of original chemical peculiarities of each magmatic cycle. The structural and orogenic influences are in any given igneous cycle much more likely to be similar than they are in different cycles. In fact, if, as modern petrology has tended to accept, crystallization differentiation is the fundamental cause of rock variation, it is difficult to see how the features we loosely regard as characterizing one petrographic province as distinct from another can arise except through differing structural histories during the magmatic cycles.[12] Hence, granting Wells' contention, we still believe it theoretically possible to effect correlations even on the basis of pneumatolytic and secondary accessories, although, of course, considerable caution is required.

The similarities shown in the heavy mineral suites we have examined (aside from the biotite-quartz diorite suite already discussed) are so tenuous and largely subjective that we would decline to extend our correlations widely without other evidence;

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[12] In this connection see especially Goldschmidt, V. M., Stammestypen der Eruptivgesteine: *Vidensk. Skrifter I, Mat-Naturv. Klasse,* No. 10, 1922.

however, the method seems to furnish some worth-while clues and can be used to supplement other methods.

The common apparent corrosion of the zircon and apatite crystals of the quartz hornblende diorites and trondhjemites gives some reason to question the commonly accepted idea that these minerals, being among the earliest to crystallize, are stable throughout the later magmatic history. If they are, indeed, partly corroded and not merely imperfectly grown crystals this change may well be sufficiently variable from place to place in the same magma body to invalidate the method of correlation by degree of "corrosion." However, the specimens examined were not numerous enough to throw light on this possibility. It seems, however, worth while to suggest that these minerals may not always survive unaltered through the entire magmatic history.

The work of Rastall and Wilcockson[13] has shown that some dikes in undoubted connection with the main mass of the Shap granite body have accessory minerals widely different from those of the main body. In conjunction with the differences shown by the endomorphic diorite we examined, this result is an additional reason for regarding the method cautiously. Nevertheless, we believe it worthy of further trial, even though not yet convinced that the possibilities of the method are very great.

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[13] Rastall, R. H., and Wilcockson, W. H., *op. cit.*, p. 616.

A METALLIC METEORITE FROM OGALLALA, NEBRASKA

H. H. NININGER, *Denver, Colorado.*

In November 1930 the writer recieved as an exchange from the Colorado School of Mines a small meteorite weighing 3300 grams said to have come from the town of Brule, Nebraska, in 1918. There is no doubt but that this is the meteorite referred to in G. T. Prior's Catalogue of Meteorites under the name of Brule.

A visit to the village of Brule a few months later, however, revealed the fact that though it had been sent in from the village of Brule this meteorite had been plowed from a field about 3½ miles northeast of Ogallala, which is the county seat of Keith county and is situated about 11 miles east of Brule. This gives the location of the meteorite as Lat. 41° 10′ N.; Long. 101° 40′ W. between the north and south branches of the Platte river in Keith county, Nebraska. The meteorite is therefore being described as Ogallala which is a larger village than Brule and is 11 miles nearer the location of the find.

This meteorite possesses some striking surface markings. The greater part of its surface is strongly pitted, but the pittings, instead of being circular, are noticeably angular and show evident traces of octahedral cleavage. These angular depressions remind one of the jagged surfaces of the great Chupaderos irons of Mexico where the two faces of those great irons seem to have been once united. It seems likely that the Ogallala iron is but a portion of a larger mass which "split up" during its flight, but travelled far enough subsequent to the "split up" so as to glaze over the angular octahedral breaks. These depressions are absent from only about one-fourth of the surface where are found the usual shallow pittings. So far as known none of the other fragments (if any) of this fall have ever been discovered.

The general form of this iron is that of a very oblique pyramid, roughly quadrangular in cross-section and tapering from the basal dimensions of 11.5 cm.×9.3 cm. to 3.2 cm.×2.2 cm. as the mass was when it came into my possession. There had been, however, a small tip of the iron previously removed by sawing. See Fig. 1.

In places the original untarnished, thin, bluish-black fusion crust shows on the ridges which separate the pittings. In the depressions the crust is much thicker and for the most part somewhat discolored by the exudation of oxide. In a few places the fusion crust is drawn out into thin wavy thread lines such as have been noted on several freshly fallen iron meteorites. These small areas are usually located on the ridges and by their orientation and distribution indicate quite certainly that the body fell with a whirling motion.

Upon cutting this small iron shows an almost uniformly compact structure with only a few small nodules appearing in the five thin slices removed. Several of these were small irregular masses of schreibersite and others inclusions of troilite, the largest a mass of schreibersite comprising only 7 sq. mm. in cross-section. The metal takes a high polish.

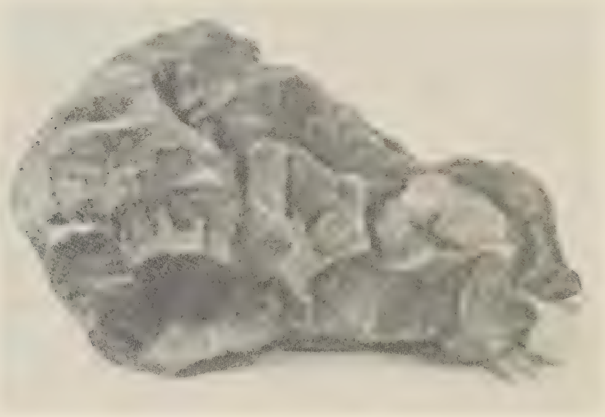

FIG. 1. External view of the Ogallala iron as it came from the Colorado School of Mines showing angular surface pittings.

Etching in weak HNO_3 quickly reveals octahedral arrangement of kamacite; but the plates are of variable thickness and are irregular in outline, the form known as swollen kamacite. For the most part they are less than 2 cm. in length and vary in width from .5 mm. to 3.5 mm. Not infrequently the plates taper at one or both ends and some are so exceedingly irregular in outline that they would not be suspected of being a part of a crystalline structure were they not definitely connected up with more symmetrical figures. The kamacite is of the hatched variety.

The intra-lamellar structure of this meteorite is really more clearly defined than the figures just described. Under a ten-power lens one finds that the bands of kamacite are each traversed by a set of very straight, clean cut, fine lines of the Neuman pattern. These are usually less than .25 mm. apart and in some cases are so near together that 32 were counted in a distance of one mm. The orientation of this intra-lamellar structure is somewhat varied but usually several adjoining plates are so uniform that the bands of an etched slice can be divided into about three groups according to the direction of the Neuman lines. This grouping is responsible for strongly contrasted areas on an etched slice showing either dull or bright according to the direction of the light. The lines vary in length from a cm. to less than a mm. on the surfaces examined.

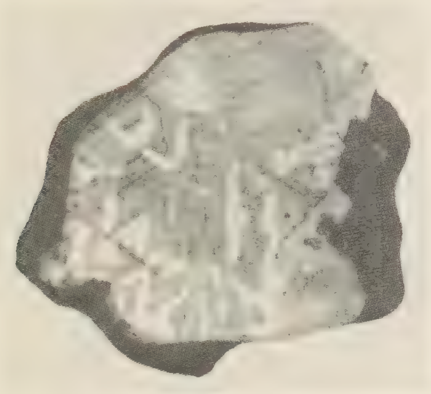

Fig. 2. An etched slice of the Ogallala iron showing swollen kamacite forming Widmanstätten figures and a zone of alteration around its edges resulting from the heat of friction during its fall.

All of the sections which were cut from near the small end of this iron show a zone of altered structure due to the heat developed during its passage through the atmosphere. The depth to which such alteration has penetrated grows less as the diameter of the iron increases and shows its greatest depths on the angular ridges or corners of the mass where it reaches a depth of 4.5 mm. near the smaller end. See Fig. 2. In the zone which has been thus effected the Widmanstätten figures show less distinctly than in the interior of the same slices and under a lens the kamacite appears distinctly flaky or granular, the numerous flakes or granules being variously oriented so as to give it a variable appearance in different lights.

The taenite in Ogallala is typical of octahedrites of this variety. In many places the thin laminae seem to be made up of two very thin sheets placed side by side. Frequently, as in several other medium octahedrites these laminae seem to thicken towards their ends and in some cases spread apart enveloping a small amount o plessite.

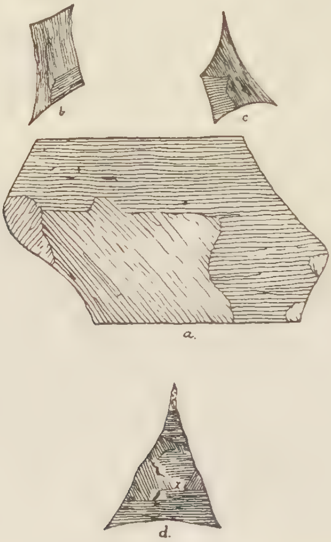

Fig. 3.

FIG. 3. Four typical plessite fields. Enlarged 5 diameters.

The plessite fields show no striking characteristics in this meteorite. Four which may be considered typical have been sketched to illustrate their structure. In some the laminae are much finer than in others. There are, however, comparatively few plessite fields and none are very large. Apparently this alloy is present in less than the normal proportions for this type of octahedrite.

A chemical analysis by F. G. Hawley gives the following:

Fe	90.10
Ni	7.93
Co	0.34
Cu	0.04
Cr	0.031
Mn	nil
P	0.164
S	0.045
C	0.048
Si	0.024
Cl	trace
O	0.48
Total	99.304

Pt. metals per ton 0.40 oz.

The main mass is in the Nininger Collection of Meteorites in the Colorado Museum of Natural History.

MEMORIAL OF FRIEDRICH J. K. BECKE*

EDWARD H. KRAUS, *University of Michigan.*

On June 18, 1931, mineralogy lost another of its stalwart leaders when Professor Friedrich Becke died in Vienna, Austria, after a long illness. Although few American mineralogists had the privilege of knowing Professor Becke personally, all are familar with his outstanding contributions to the science. These were so signal that many honors were bestowed upon him, among which was his election as honorary life fellow of the Mineralogical Society of America in 1928.

FRIEDRICH J. K. BECKE
1855–1931

Friedrich Johann Karl Becke was born at Prague, on December 31, 1855. His father was a book dealer, but later in life became a railroad official. In preparation for admission to the university Professor Becke studied at the gymnasiums in Prague, Budweis, and Vienna. In 1874 he entered the University of Vienna where he spent six years studying mineralogy and petrography under the guidance of the eminent Gustav Tschermak, and in 1880 the doctorate was conferred upon him. In 1881 he qualified for a university position in petrography at Vienna, and the following year was appointed assistant professor of mineralogy at the University of Czernowitz. He held this position for four years when he was advanced to a full professorship. From 1890 to 1898 he was professor of mineralogy at the German University at Prague. He then returned to his alma mater, the University of Vienna, where he continued in active service until his retirement in 1927.

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* Read by title at the Twelfth Annual Meeting of the Mineralogical Society of America, Tulsa, Oklahoma, December 29, 1931.

In this brief memorial it is not possible to refer at length to his many and varied achievements, for throughout his academic life he was an exceedingly active and brilliant investigator. Upon the occasion of his seventieth birthday, in 1925, a memorial volume was published in his honor by his colleagues, friends, and former students, which contains a record of his scientific publications numbering over 250 titles. Professor Becke did not confine his efforts to any one field but contributed to the advancement of several phases of the science, that is, to the development of descriptive mineralogy, geometrical and chemical crystallography, petrography, and crystal optics. His contributions to our knowledge of etch figures are also well known.

Eminent as Professor Becke was as a teacher and investigator, he was equally distinguished as an editor, for Tschermak's Mineralogische und Petrographische Mitteilungen was published for many years under his immediate direction. He also revised Tschermak's well known textbook on mineralogy several times. Furthermore, for a considerable period he served as the general secretary of the Royal Austrian Academy of Sciences in Vienna.

Many high honors came to Professor Becke in his native country and from abroad, among which were the awards of the Eduard Suess medal of the Geological Society of Vienna and of the Wollaston medal of the Geological Society of London. At the time he retired from active service in 1927, he received the medal for distinguished service to the Austrian Republic. Moreover, he was frequently honored by election to membership in learned and scientific societies, of which those of Göttingen, Berlin, Munich, Oslo, Paris, Rome, St. Petersburg (Leningrad), and Prague may be mentioned. That he was on honorary life fellow of our society has already been referred to.

It may well be said that Professor Becke was one of mineralogy's intellectual giants. His death adds another name to the list of illustrious teachers and investigators in Europe who worked so heroically to place mineralogy in its present advanced position, and who have died in recent years: Lewis (1926), Baumhauer (1926), Tschermak (1927), Groth (1927), Doelter (1930), Wülfing (1930), Beckenkamp (1931), and Becke (1931).

THE NEGATIVE CRYSTAL CAVITIES OF CERTAIN GALENA AND THEIR BRINE CONTENT

M. J. Buerger, *Massachusetts Institute of Technology.*

ABSTRACT

Galena from certain localities, notably Joplin, is characterized by containing numerous voids. In simple cases, these are cubo-octahedral negative crystals; in other instances, they are more complicated catacomb-like voids based on the cubo-octahedral motif. These are brine filled; on breaking the crystal, the brine crystallizes as sodium chloride cubes in parallel position with the galena. Head has previously described these cubes, implying that they occurred as halite contemporaneous with and intergrown with the galena.

Head[1] has recently called attention to the sodium chloride content of galena. He implies that the salt occurs as solid halite, and that the age of the salt is roughly contemporaneous with that of the galena, for he says, in part:

> The existence of *halite* on galena surfaces is a matter that affords some grounds for amplification, at least theoretically. The mere fact of its presence is suggestive and might serve for entertaining the premise of the possible occasion of other soluble

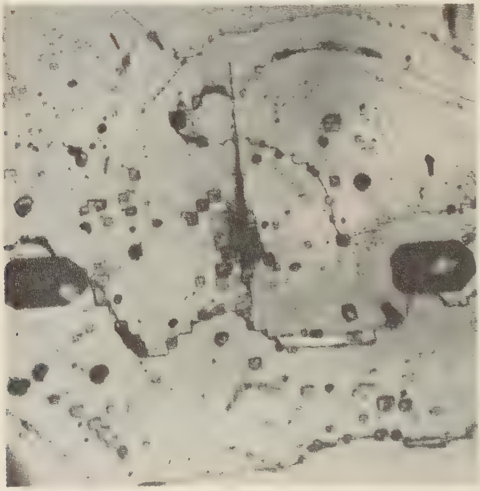

FIG. 1. Negative crystal cavities of cubo-octahedral habit in Joplin galena, ×18. The little squares are sodium chloride crystals which have precipitated on the cleavage surface from the brine contained in these and nearby cavities.

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[1] R. E. Head. The Cleavage Surfaces of Galena: *American Mineralogist*, **16**, 1931, 348–350.

or insoluble salts as *natural surface constituents* on sulphide minerals [Italics by M.J.B.].

The present writer contends that the sodium chloride is present as brine in negative crystal voids in the galena, and that evaporation of this brine precipitates the sodium chloride on the new cleavage which exposes the cavity.

NEGATIVE CRYSTAL VOIDS. Negative crystals are of common occurrence in galena, especially in the Joplin galena. The smaller examples of these voids are essentially simple and tend to duplicate the normal habit of the crystal exterior in the negative, but with rather a marked tendency toward rounding of all edges and corners. Thus, the usual negative crystal habit of the Joplin galena is cubo-octahedral, as shown in Figure 1. Larger examples have more irregular shapes although it is usually not difficult to discover the cubo-octahedral motif upon which they are based (Figure 2).

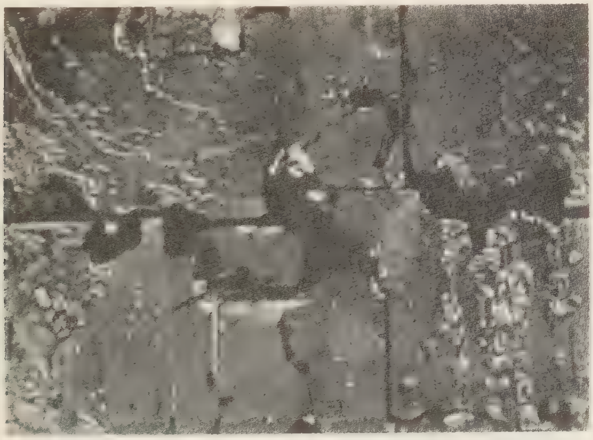

FIG. 2. Connecting voids in Joplin galena, ×18. This photograph was taken by combined normal and oblique illumination. The chains and masses of light material are sodium chloride crystals precipitating on the cleavage surface from brine derived from these cavities.

In order to gain a correct background for an understanding of the origin and placement of negative crystal cavities in galena, it is necessary to refer the reader first to a previous article devoted to the discussion of *lineages*.[2] Examination of a large number of negative crystal cavities of different types brings out the fact that a considerable proportion of them occur obviously in lineage boundaries (Figure 3). Because of the impossibility of gaining a correct appreciation of the third dimension in an opaque mineral like galena, and in view of the plausibility of the idea, as explained below, it appears very probable that most, or perhaps all, of the negative crystals do actually occur in lineage boundaries, and that those which do not show an obvious connection with this feature, probably would if a cleavage somewhat above or below the one under examination could be seen. The origin of the rather profuse negative crystals of Joplin galena probably thus comes about largely as an irregular growing-over of the exterior surfaces of crystals whose lineages have forged ahead independently in such a way that the exterior of the crystal takes on the appearance, in a somewhat less extreme fashion, of a group of crystals "in parallel position." This origin accounts for the fact that crystals rich in lineages are also rich in irregular negative crystals.

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[2] M. J. Buerger. The Significance of Block Structure in Crystals: *American Mineralogist,* **17,** pp. 177–191, 1932.

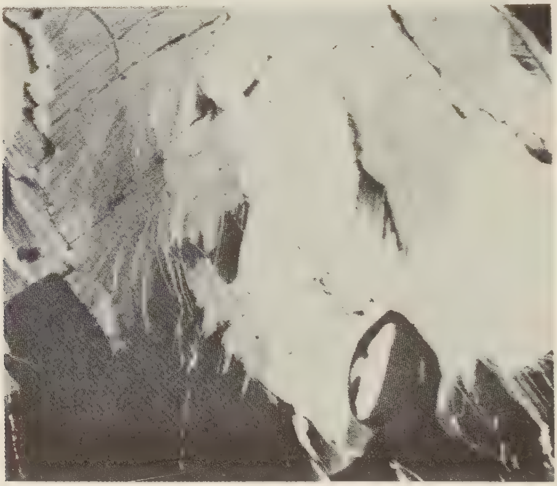

FIG. 3. Cleavage surface of Joplin galena, ×65, specimen slightly tipped to display lineages. The two rounded black areas about half an inch across, in the right and left lower centers, are negative crystal cavities. The blocks of various shades and irregular shapes are lineages. The occurrence of negative crystals at lineage boundaries is obvious.

In line with this is the presence of catacomb-like cavities or systems of cavities connected by tabular openings (Figure 2), and linearly arranged strings of cavities. The line of connection or line of alignment in the case of unconnected cavities, is evidently some lineage boundary. This may or may not be indicated on the cleavage surface examined, because of the third dimension difficulty. The outermost systems of catacombs usually connect directly with the exterior of the crystal. When this is the case the surfaces of the cavities are frequently either corroded or filled with various other minerals, usually the common secondary products. In all other instances, the interior surfaces of the negative crystals are exceedingly lustrous and show no signs whatever of any alteration. In some cases normal, brilliant crystal faces may be made out in the interior, in others, the interior has an appearance somewhat akin to that of the surface of irregular fused lumps of glass. Head's term, "pebbled" evidently refers to some of these surfaces of special type which are well described by this term. Similarly, Head's allusion to slickensiding (page 347, legend to Head's Figure 2) evidently comes from very beautiful rounded examples of oscillation striations.

THE BRINE CONTENT OF CERTAIN GALENA

Mr. Head is correct when he says that sodium chloride occurs with some of the galena crystals, but the writer believes he is incorrect in implying that sodium chloride occurs as halite. As a matter of fact it occurs as salt water in negative crystal voids of the crystals; on breaking the cube of galena, the salt water spreads and covers the bright new cleavage surface and on evaporation crystallizes as salt in parallel orientation with the galena. The evidences for this correction are as follows:

(a) Mr. Head's photograph given as his original Figure 3, showing halite on the galena cleavage, indicates that the sodium chloride is *on* the new galena *cleavage* and did not grow *in* and *with* the galena, to be exposed by later cleavage. This is clearly indicated by the fact that the sodium chloride crystals have preferentially chosen the regions of *tear lines*[3] as foci of crystallization. The tear lines can be seen through the transparent cubes. They must, therefore, antedate the cubes, for it is clear from the very nature of tear lines that it would be impossible to form them under other crystals. Furthermore, assuming that the sodium chloride was present as crystals in the galena, the cleaving of the galena would have required the simultaneous cleaving of the sodium chloride crystals. There is no trace of this in the photograph.

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[3] A discussion of these is given in: M. J. Buerger, The Cleavage Surfaces of Galena; to appear in a later issue of *The American Mineralogist*.

(b) Artificial sodium chloride will precipitate as crystals in parallel position on a galena cleavage surface, from evaporation of a concentrated water solution.

(c) On breaking a large number of galena crystals from Joplin, not one was found to have intergrown halite, but many were found to have cavities filled with brine. The cavities are in the form of regular to complex negative crystals, as previously described. The cavities have highly lustrous, metallic surfaces, with not a trace of corrosion in evidence.

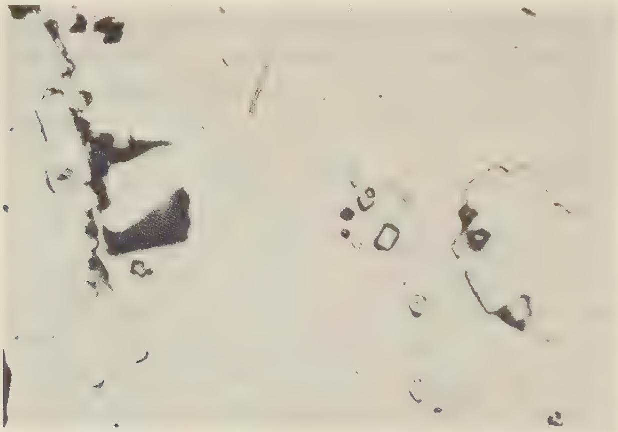

FIG. 4. Cleavage surface of Joplin galena, ×65. This photograph plainly shows the sodium chloride cubes precipitating from brine. The liquid was derived from the complex negative crystal cavity.

In several fortunate instances, the actual brine was visually detected *in* the cavity exposed by cleavage. In such instances the cavity had the appearance of being full, but this is a fleeting observation which had to be made while the cavity was in the process of losing its liquid to the surrounding surface by reason of the spread of the liquid as a thin film. This liquid has a taste characteristic of a very concentrated brine. As it spreads to the surrounding cleavage its presence is usually indicated by the "oily" appearance of the cleavage surface due to interference of light in the thin film. The crystallization of the sodium chloride begins at once, and can be completely followed (See Figures 1, 2, and 4).

In most instances, after breaking a galena crystal the liquid has already spread or has been scattered by the mechanical jar of cleaving before one has a chance to view it in place. In all such cases, the "oily" appearance of the surface film or the occurrence of scattered brine drops is so patently associated with the cavity that no doubt can be entertained regarding the origin of the liquid. The crystallization can be watched as previously indicated, however.

The writer submits that the cases of halite occurring with galena described by Head are other instances of crystallization of brine from negative crystal cavities as above described. For those interested in the origin of the Mississippi lead-zinc deposits, it appears that an adequate sample of the solution present at the time of crystallization of the galena might be had in the following simple way: A relatively large lot of galena, known from preliminary breaking to be of the kind containing brine-bearing cavities, might be crushed under careful conditions and leached with a relatively small amount of water. After concentration, a thorough analysis of the water would give a set of data of incomparable value in the study of the origin of this type of deposit. From the nature of the negative crystal cavities, it appears certain that the contained solution would give a true sample of the solution which precipitated the galena, less whatever has been lost within the cavity by actual precipitation. Is it not possible that a search for filled voids in galena and other minerals from deposits of other than the Mississippi Valley type, will also furnish samples of the solution from which the crystals were deposited?

Dr. W. H. Newhouse has already instituted such search, with most gratifying positive results. These are detailed in a paper entitled "The composition of vein solutions as shown by liquid inclusions in minerals," which is about to appear in *Economic Geology*.

CHEMICAL COMPOSITION OF CUPROTUNGSTITE

Waldemar T. Schaller, *Washington, D. C.*

The occurrence of cuprotungstite at Cave Creek, Arizona, has been described by Hess.[1] Its association with ferberite and with scheelite is shown by him in a colored plate (Pl. XVII).

Two samples were analyzed, one hard and compact and the other soft and friable. Two analyses were made of each sample, using HCl and HNO_3 as the solvents. It was not realized when the analyses were begun that so considerable a quantity of insoluble gangue was present in both samples. The role played by the calcium soluble in the acids is not known. It may belong to the cuprotungstite, to the insoluble matter, to scheelite, or to fluorite. Fluorine was not looked for in either sample. The water passes off only above 110°C.

Analyses of Cuprotungstite from Cave Creek, Arizona

Solvent	Hard material			Soft material		
	1	2	Average	1	2	Average
	HCl	HNO_3		HCl	HNO_3	
Insoluble	71.75	71.84	71.80	33.14	34.08	33.61
WO_3	13.10	13.24	13.17	35.47	35.26	35.37
CuO	7.85	7.69	7.77	19.89	19.26	19.58
CaO	0.88	1.08	0.98	1.72	1.74	1.73
MgO	0.20	0.12	0.16	0.19	0.34	0.27
Fe_2O_3	0.61	0.68	0.65	1.52	1.03	1.28
H_2O	4.35	4.32	4.34	6.43	6.46	6.45
	98.74	98.97	98.87	98.36	98.17	98.29

The average analyses of both the hard and the soft material are given below with the insoluble gangue and the iron oxide deducted, and the remainder recalculated to 100 per cent. The insoluble gangue in both samples contained considerable clay-like material and had a considerable water content. The percentage of water in the insoluble gangue was determined on both samples, after decomposition of the cuprotungstite with HCl, solution of the separated oxide of tungsten in ammonia, washing, and air drying for a week. The insoluble gangue of the hard material contained 2.63 per cent H_2O and that of the soft material 3.49 per cent. Allocating this water to the gangue, the average analyses of the two samples can be restated in the form given in the table below which also shows the average analyses of the cuprotungstite recalculated to 100 per cent.

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[1] Hess, F. L., Tungsten minerals and deposits: *U. S. Geol. Surevy, Bull.* **652,** pp. 32–33, 1917.

AVERAGE ANALYSES OF CUPROTUNGSTITE WITH INSOLUBLE GANGUE DEDUCTED

	Hard material		Soft material	
	Analysis	Recalculated	Analysis	Recalculated
WO_3	13.17	55.36	35.37	59.04
CuO	7.77	32.66	19.58	32.68
CaO	0.98	4.12	1.73	2.89
MgO	0.16	0.67	0.27	0.45
H_2O (in mineral)	1.71	7.19	2.96	4.94
	23.79	100.00	59.91	100.00
Gangue (ignited)	71.80		33.61	
Fe_2O_3	0.65		1.28	
H_2O (in gangue)	2.63		3.49	
	98.87		98.29	

The ratios obtained from the recalculated average analyses, are as follows, taking that of WO_3 as 1.00.

RATIOS OF RECALCULATED AVERAGE ANALYSES OF CUPROTUNGSTITE

	Hard material			Soft material		
WO_3	0.239		1.00	0.255		1.00
CuO	0.410			0.411		
CaO	0.073	0.500	2.10	0.052	0.474	1.86
MgO	0.017			0.011		
H_2O	0.399		1.67	0.274		1.08

In the hard sample the ratios of the bases to WO_3 is slightly over 2:1; in the soft sample, slightly under. The average is 1.98 to 1.00 or practically 2:1. In the soft sample, containing the smallest quantity of gangue, the ratio of water to WO_3 is almost 1:1, in the hard sample it is somewhat greater. These ratios indicate clearly that the formula of cuprotungstite is $WO_3 \cdot 2CuO \cdot H_2O$.

If the $CaO + MgO$ be considered as belonging to scheelite and the corresponding quantity of WO_3 allowed for and deducted, then the ratio of CuO to WO_3 is 2.76 in the hard sample, and 2.14 in the soft sample; insufficient evidence for doubting the 2:1 ratio of base to acid in the mineral. This ratio does not even approach the 1:1 ratio, as given by Dana and by Hess, no matter what assumption is made with reference to the role played by the calcium.

The only recorded analysis of essentially cuprotungstite is the first one listed by Dana.[2] If the 2.00 per cent CaO therein reported be ascribed to scheelite and the corresponding quantity (8.31 per cent) of WO_3, deducted, the ratios of the analytical figures representing cuprotungstite yield the same formula as deduced from the analysis of cuprotungstite from Cave Creek, namely, $WO_3 \cdot 2CuO \cdot H_2O$.

RATIOS OF DOMEYKO'S ANALYSIS OF CUPROTUNGSTITE FROM CHILE, AFTER ALLOWING FOR IMPURITIES

WO_3	48.17	.2076	1.00 or 1
CuO	30.63	.3848	1.85 or 2
H_2O	4.62	.2567	1.24 or 1
Fe_2O_3	2.53		
SiO_2	3.87		
Scheelite	10.31		
	100.13		

If it be assumed that no scheelite was present and that the CaO belongs to the cuprotungstite and its ratio be combined with that of CuO, as was done with the analysis of the mineral from Cave Creek, then the ratio of $WO_3 : CuO + CaO : H_2O$ is 1.00:1.73:1.06, yielding the same formula as before, namely $WO_3 \cdot 2CuO \cdot H_2O$.

The other three analyses listed by Dana are probably impure mixtures of cuprotungstite and scheelite, as noted by Hess. The name cuproscheelite[3] should be discarded, as it obviously was applied to a mixture, as stated by Hess.

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[2] Dana, E. S., System of mineralogy, 6th ed., **1892,** 988. Analysis by Domeyko, on material from Chile.

The analyses of cuprotungstite from Arizona, supplemented by one analysis of material from Chile, has shown that its chemical composition is that expressed by the formula $WO_3 \cdot 2CuO \cdot H_2O$.

A specimen of cuproscheelite from Kern County, California, from an old collection, with a label of Henry G. Hanks, San Francisco, and probably an authentic specimen, when examined microscopically, was seen to be scheelite with admixed cuprotungstite, which colored the scheelite greenish.

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[3] The name cuproscheelite would apply better to a mineral analogous to scheelite but with CuO in place of CaO. Its formula would then be $CuO \cdot WO_3$. No such mineral is known.

TWO NEW OCCURRENCES OF PIEDMONTITE IN CALIFORNIA[1]

EVANS B. MAYO, *Cornell University.*

During the winter of 1929–'30, in the course of a petrographic study of some metamorphic rocks collected the previous summer in northeastern Madera County, California, it was discovered that the rare mineral piedmontite occurred in one of the specimens as a replacement of biotite. A year later, a fragment of piedmontite-sericite schist, from a locality only a few miles from that at which the former specimen had been obtained, was sent to the Geology Department, at Cornell University, for identification. Since all the previously-noted occurrences of this mineral in California seem to be in fragmental rocks, it was thought worth while to record these new localities, together with such data as could be obtained on the origin and nature of the material. A brief historical résumé is inserted, because very little information on this subject seems to be available in English.

Piedmontite, a manganese-bearing mineral of the epidote group, was first noted at Saint Marcel, in Piedmont, Italy.[2] The first investigator to write concerning this substance seems to have been Cronstedt, who, in 1758, named the mineral "röd Magnesia." It was analyzed in 1790 by the Chevalier Napione, who termed it "Manganèse rouge." Haüy, in 1801, on the basis of Napione's analysis, designated the substance as "Manganèse oxidé violet silicifère." In 1803, Cordier, on the basis of a new analysis[3] recognized the mineral as an "Épidote manganésifère," a name which was later adopted by Haüy.[4] It thus became known to English writers as "manganesian epidote," and to German ones as "Manganepidot." Werner, in 1817, chose for this mineral the name "Piemontischer Braunstein." The name piedmontite ("Piemontit"), proposed in 1853 by Kenngott, has largely taken the place of other designations for manganese-bearing epidote, although the term withamite*[5] may be used for the monoclinic mineral, of positive optical character, when it contains but a small amount of manganese;[6] and the somewhat analogous orthorhombic form is known as thulite. A very rare monoclinic form, with negative optical character, and containing as much as 4.52 per cent Mn_2O_3, is called mangan-epidote. It occurs in the manganese ore deposits of Jakobsberg, in Sweden.[7]

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[1] Published by permission of the California State Division of Mines.

[2] Hintze, Handbuch der Mineralogie, vol. **2**, pp. 254–255, 1897.

[3] Cordier, L., Analyse du Minéral connu sus le nom de Mine de Manganèse violet du Piémont, faite au Labratoire de l'Ecole de Mines: *Journ. de Min.*, vol. **13**, p. 135, 1803.

[4] Haüy, R. J., Traité de Mineralogie, vol. **2**, p. 575, 1822.

Piedmontite was for a time thought to be orthorhombic, like zoisite and thulite,[8] but it was shown to be monoclinic by Des Cloizeaux,[9] whose conclusions were verified by Bücking[10] and Laspeyres.[11] Besides the original locality at Saint Marcel, mentioned above, the mineral has been found at a number of widely distributed places in various parts of the world, some of which are listed at the end of this paper. A discussion of the Californian occurrences follows.

THE CALIFORNIAN OCCURRENCES

This is not the first notice of piedmontite from California, for it was found by Rogers in a thin section of quartz prophyry in a boulder from the Pliocene or Pleistocene gravels at Pacific Beach, in San Diego County. The piedmontite was "a secondary mineral, replacing some original ferromagnesian mineral, probably biotite."[12] It has also been reported by Reed and Bailey, as a detrital constituent in the "granitic" zones of lacustrine sediments in the Lazard area, west of Lost Hills, in the southern part of the San Joaquin Valley.[13] The material from the two new localities, which form the subject of this paper, will now be considered.

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* The asterisk is employed to designate articles not seen by the writer.

[5] Brewster, D., *New Edinburgh Journ. Sci.*, vol. **2**, p. 218, 1825.

[6] Heddle, Minerals New to Britain: *Mineralog. Mag.*, vol. **5**, p. 15, 1884. Gives a chemical analysis of withamite.

[7] Flink, G., *Zeitschr. f. Kryst.*, vol. **15**, p. 88, 1889.

[8] Breithaupt, A., Mineralogische Studien, *Berg-und Huettenmaennische Zeitung*, vol. **24**, pp. 341–343, 1865.

[9] Des Cloizeaux, Manuel de Mineralogie, vol. **1**, p. 254, 1862.

[10] Bücking, H., Ueber Krystallformen des Epidot: *Zeitschr. f. Kryst.*, vol. **2**, pp. 384–385, 1878.

[11] Laspeyres, Die krystallographischen und optischen Eigenschaften des Manganepidot (Piemontit): *Zeitschr. f. Kryst.*, vol. **4**, p. 435, 1880.

[12] Rogers, A. F., Notes on Rare Minerals from California: *School of Mines Quarterly*, vol. **33**, p. 378, 1912.

[13] Reed, R. D., and Bailey, J. P., Subsurface Correlation by Means of Heavy Minerals: *Bull. Am. Assoc. Petrol. Geol.*, vol. **11**, pp. 359–368, 1927.

1. Occurrence in Piedmontite-Sericite Schist

The small specimen of pink, piedmontite-sericite schist was collected by Mr. W. E. Selbie, a prospector, who states that it occurs near Shadow Lake, in northeastern Madera County, as a "vein" perhaps fifty feet wide, and traceable for about a mile. This small fragment was found to contain better material for study than that in the specimen previously collected, hence it is discussed first.

Megascopic character. The rock is of pinkish-red color, with a silky luster due to abundant sericite. The specimen tends to split along two well-defined directions of schistosity, that make angles of about 25° or 155° with one another. Small knots in the sericitic matrix indicate the positions of minute grains of quartz, as may be seen on the rough surfaces which have broken normal to the schistosity and exposed the cores of the little knots. Minute, dull white specks mark the positions of feldspar grains.

Irregularly-shaped, black stains occur in the sericite along the surfaces of schistosity. Some of this black material, scraped off the specimen, yielded, with sodium carbonate, the familiar test for manganese. With the aid of a hand lens, minute, prismatic crystals of dark-red piedmontite can be seen, embedded in a matrix which apparently consists mainly of pale pink sericite.

Microscopic character. Two thin sections were prepared, one parallel to the more prominent rock cleavage, and one perpendicular to both cleavages. These sections are referred to as "A" and "B," respectively.

Section A reveals an extremely fine-grained mosaic, apparently of quartz and feldspar individuals with a diameter of about .01 mm., in which are embedded abundant wisps of sericite, "streams" of piedmontite needles, accompanied by minute (.05 mm.) crystals of apparently colorless garnet (Fig. 1A), and angular fragments of quartz, reaching 0.4 mm. in diameter. These quartz fragments occasionally show by their outlines the trace of one or more crystal faces. One shattered, but nearly complete, subhedral grain was seen near the edge of the section. A lens-shaped quartz grain, 3.5 mm. long, exhibits, between crossed nicols, the cataclastic texture. It seems as though quartz grains, or crystals, as large as this one were unable to resist deformation and granulation which the smaller ones escaped.

Occasional rectangular areas, probably marking the positions of former sanidine crystals, occur in the section. These palimpsests are about .5 to .7 mm. long and .3 to .4 mm. wide, and consist of a mosaic of recrystallized, untwinned feldspar material, with refractive indices less than canada balsam, together with flakes of sericite, and a pale brown mica having $2V$ = about 4° or 5°. Irregular bodies and dusty streaks of manganese oxide occur sparingly in the section. A few minute euhedra of zircon are present, and tiny, needle-like prisms of secondary apatite are fairly abundant, though scarcely noticeable.

Besides the mineral constituents noted above, a few irregular, apparently lithic, fragments, 1 or 2 mm. long, are to be seen. The mineral composition of these fragments is somewhat similar to that of the enclosing rock, except that the former are much poorer in sericite, and are highly charged with manganese oxide.

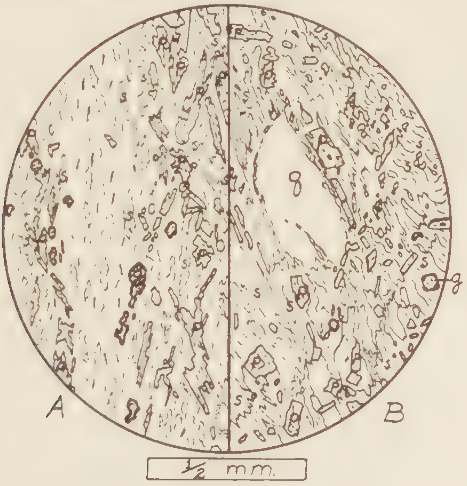

Fig. 1. Sections of piedmontite-sericite schist.
g = garnet; p = piedmontite; q = quartz; s = sericite.

In section B, which was cut at right angles to the schistosity, the two intersecting sets of rock cleavage can be seen. The piedmontite occurs mainly as tiny rectangles and rhombs, representing cross-sections of prisms like those in section A, although a few elongated grains were seen here also. These are unoriented with respect to the schistosity of the rock. These unoriented crystals, and especially the smaller ones, are more nearly euhedral than the oriented prisms of section A.

Character of the piedmontite. The elongated individuals of piedmontite measure from .2 to .3 mm. in length, and .02 to .05

mm. in thickness. Occasionally the crystals show faces belonging to the forms (100), (001), and (h0*l*), although most of the grains are without recognizable crystal forms. One individual, lying on the orthopinacoid, and so oriented that the *b*-axis is horizontal, is shown in Fig. 2. The axial colors, seen when the indicated directions are parallel to the direction of vibration of the lower nicol, are shown in the figure. A positive, acute bisectrix interference figure, with large axial angle, and axial plane perpendicular to the long dimension of the crystal, was obtained from the horizontal grain of Fig. 2. Crystals showing axial colors like those indicated on the lower grain, yield, in convergent polarized light, an apparently negative interference figure, with the trace of only one optic axis, visible at the extreme edge of the field. These tests, supported by a comparison with slides of the piedmontite from South Mountain, Pennsylvania, so ably described by George H. Williams,[14] indicate beyond doubt that the material from California has the usual pleochroism scheme: X = orange, to lemon-yellow; Y = amethyst, or amethystine red; Z = carmine. A study of the piedmontite occurring in spherulites in the rhyolite of South Mountain reveals no essential difference in the axial colors of the Pennsylvanian and Californian minerals.

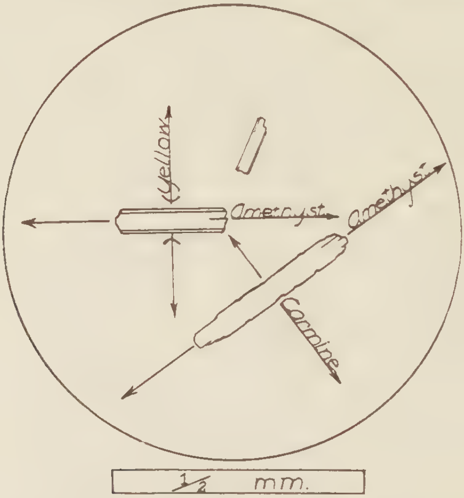

FIG. 2. Axial colors of crystals in piedmontite-sericite schist.

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[14] Williams, George H., Piedmontite and Scheelite from the Ancient Rhyolite of South Mountain, Pennsylvania: *Amer. Jour. Sci.* [3], vol. **46**, pp. 50–57, 1893.

The piedmontite in both sections occasionally contains minute inclusions. In some cases, these appear to be quartz, similar to that of the groundmass; in other cases there are lines of round, or oval-shaped bodies, arranged parallel to the *b*-axis of the host. From their shape and extreme negative relief, the latter inclusions are thought to be liquid-filled cavities.

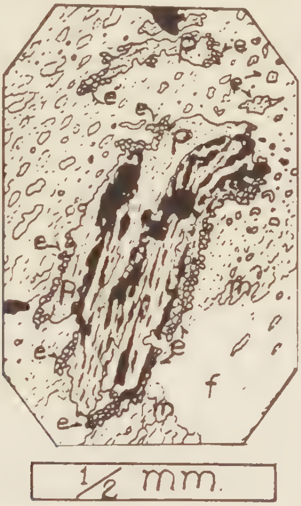

Fig. 3. Showing a flake of altered biotite in the metamorphosed volcanic rock. e = epidote; f = feldspar; m = mica (secondary biotite); p = piedmontite; black is manganese oxide.

History of the rock. Evidence as to the nature of the original rock is furnished by the remnants of quartz phenocrysts, or fragments of former quartz crystals, as seen in the sections. When such a crystal, or crystal fragment, is nearly complete, the shape is extremely suggestive of the phenocrysts of high-quartz (inverted to low-quartz), found in acid lavas.[15] The fact that so many of the quartz crystals are now represented by fragments only, suggests that the original deposit may have been fragmental, such as ash, or tuff, instead of lava, but it is thought that this fragmentation of earlier complete crystals may possibly have been due to later orogenic movements. Whether or not the original rock was a lava, it is evident that granulation, produced by directed pressures, resulted in recrystallization, which gave rise to the secondary quartz and feldspar of the groundmass. Apparently the pale brown mica, mentioned above, crystallized at this time, and was followed by garnet and piedmontite. Sericite replaces nearly every piedmontite grain to a slight extent, but is never enclosed by the latter; hence this mica would seem to be restricted to a narrow time interval, near the close of crystallization of the piedmontite, and perhaps for a time thereafter. It is probable that the pink color of the sericite is due to small amounts of manganese taken up by the mica as it partially replaced the manganesian epidote. The age relations of the apatite and manganese oxide with respect to the other secondary minerals remain uncertain, but the apatite is earlier than sericite.

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[15] Rogers, A. F., Natural History of the Silica Minerals: *Am. Min.*, vol. **13**, p. 88, Fig. 1, 1928.

2. Occurrence as a Replacement of Biotite in a Metamorphosed Volcanic Rock

The specimen in which this occurrence of the piedmontite appears, was collected at the summit of the eastern end of Volcanic Ridge, in northeastern Madera County. (See the Mt. Lydell topographic sheet, U. S. Geol. Survey.) It is light, bluish gray in color, with schistose structure. With the hand lens, abundant grayish-white feldspar crystals, colorless, glassy quartz grains, and flakes and pseudohexagonal tablets of dark brown biotite can readily be distinguished. These minerals are embedded in an aphanitic, gray matrix.

Microscopic character. In the thin section, large, fractured crystals of quartz, reaching 3 mm. in diameter, are the most conspicuous objects. The shapes of some of the crystals suggest that nearly all of the quartz individual is still present; missing parts, and isolated fragments may often be accounted for by fracturing due to movements along surfaces of schistosity. The traces of such surfaces are easily seen when the analyzer is thrown out of position. These traces pass directly through the quartz grains, the two halves of which may be slightly offset, or, quite commonly, one portion is represented only by a few small fragments strewn along the surface of schistosity. In spite of the amount of fracturing and breaking up, very little recrystallization of the quartz has taken place. The crystal fragments reveal, by their shapes, a former euhedrism, which has been considerably subdued, apparently by magmatic resorption. Embayments and enclosures of the groundmass in the quartz are common.

With crossed nicols, numerous crystals and crystal fragments of plagioclase, and occasionally of microcline (by inversion from sanidine under directed pressure?), seldom attaining a diameter as great as 1.5 mm., are plainly revealed. The plagioclase contains abundant minute grains of epidote, flakes of light, greenish-brown biotite (interference figure almost uniaxial), and granules of a black, opaque substance, which chemical tests indicate to be an oxide of manganese.

Around and between these larger crystals is a very fine-grained matrix, apparently of quartz and feldspar, in which are embedded flakes of the greenish-brown mica, irregular bodies of manganese oxide, fractured, euhedral crystals of apatite, grains of epidote, and altered remnants of what appears to have been biotite. These remnants are perhaps the most interesting feature of the rock.

THE ALTERED PRIMARY MICA. Flakes of this mineral averaged about .7 mm. in length, and .4 mm. in width. The mica-substance remaining is light greenish-brown, like that occurring as secondary inclusions in the plagioclase, and scattered through the groundmass. The cleavage traces of the mica are commonly marked by lines of manganese oxide; granules of epidote usually form a fringe around the mineral, and are occasionally developed along the cleavage traces. Most interesting of all are small, elongated, or spindle-shaped bodies of piedmontite, grown along the cleavage of the mica. A few epidote-fringed grains of piedmontite also occur in the groundmass of the rock. Both occurrences are illustrated in Fig. 3. In some cases the pleochroism is nearly as strong as that of the South Mountain, Pennsylvania, piedmontite, but in many of the grains the axial colors are quite faint, and are commonly more intense in the center of the grain, grading into the colors of common epidote on the edges.

The transmitted light which vibrates parallel to the long dimension of the piedmontite bodies, in nearly every case is orange yellow, and that vibrating perpendicular thereto is always some shade of rose or carmine. Rarely, the light vibrating parallel to the length of the grains is pale amethyst in color.

From this it would appear that the piedmontite crystals are tabular, due to their having grown along cleavage planes in the mica; that the shortest dimension of the tablets is always parallel to Z, or nearly so, and that the longer diameters are approximately parallel to X and Y, but that most of the individuals are so oriented as to appear elongated parallel to X.

ORIGIN OF THE ROCK. The nature, relations, and shapes of the original constituents leave no doubt that the rock is of volcanic origin, but here again there is some doubt as to whether it was a lava or a tuff. The primary constituents were quartz, plagioclase (more basic than albite), a little potash feldspar (possibly sanidine) and biotite; hence the original rock is thought to have been a dacite, or a dacite tuff. In this rock the apatite is also a primary constituent; the greenish-brown biotite is secondary, and was followed by piedmontite, manganese oxide, and epidote. The dynamic conditions through which this rock has passed were much less severe than those which obtained during the metamorphism of the schist from Shadow Lake. Hydrothermal solutions were probably present at high temperatures only, since sericite is completely absent, even though the materials to form it were present.

OTHER OCCURRENCES OF PIEDMONTITE

In searching the literature on the various occurrences of piedmontite, the information obtained from Hintze's Handbuch,[16] in the paper by Williams,[17] and in a paper recently published by Lausen,[18] was especially helpful. The localities mentioned below are presented in the order given by Williams in 1893, and the more recently-discovered occurrences are introduced in their proper places.

With manganese ore deposits, the mineral occurs at San Marcel, Italy, with braunite, quartz, tremolite, calcite, violan, greenovite manganese garnet, manganese-bearing mica, and tourmaline;[19] at Viù, Italy, as needle-like crystals in a quartz vein traversing mica schist; and at Mezzenile, Italy, with braunite.[20*]

At Jakobsberg, in Sweden, the optically negative mangan-epidote is found with light yellow titanite, barite, manganophyllite, calcite, and a light yellow pyroxene.[21] Associated with the manganese ore deposits of India, piedmontite occurs in the Nagpur district, in Jhabua State, and in Nárukot State, as nodules in crystalline limestone, on schistosity planes in sericitoid phyllites, as fine-grained patches in epidote rock, with quartz as cavity linings in apatite-spessartite-piedmontite rock, and as rose-pink patches in granite which has absorbed portions of the manganiferous series (Jothvád, Nárukot State), etc.[22]

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[16] Hintze, *loc. cit.*

[17] Williams, *loc. cit.*

[18] Lausen, Carl, Piedmontite from the Sulphur Spring Valley, Arizona: *Am. Mineral.*, vol. **12**, pp. 283–287, 1927.

[19] Hintze, *loc. cit.*

[20*] Jervis, quoted by Hintze.

[21] Hintze, *loc. cit.*

In spherulites, or as veins in eruptive rocks, the mineral occurs at Glencoe, Scotland (withamite)[23] and at South Mountain, Pennsylvania. (In spherulites, with quartz, and at times with scheelite.)[24]

As a secondary constituent of eruptive rocks, piedmontite has been noted in the "porfido rosso antico," at Djebel Dokhan, Egypt;[25] in the quartz porphyries near Annapolis, Missouri;[26] in the granulite of Haute Loire, France;[27] at South Mountain, Pennsylvania (microscopic constituent of the ancient lavas); at Pacific Beach, San Diego County, California (in a boulder);[28] in a basic andesite at Sulphur Spring Valley, Arizona;[29] and in Madera County, California.

As a constituent of crystalline schists, the mineral is found in chlorite-sericite gneiss and in glaucophane schists in Japan;[30] on the Island of Groix, France;[31] in gabbro-diorite, as an alteration product of hornblende, at Chichibu, Japan;[32*] and in piedmontite-sericite schist in Madera County, California.

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[22] Fermor, L. L., The Manganese Deposits of India: *Mineralogy, Mem. Geol. Surv. of India*, vol. **37**, pp. 187–191, 1909.

[23] Brewster, D., *loc. cit.*

[24] Williams, *loc. cit.*

Bascom, Florence, The Ancient Volcanic Rocks of South Mountain, Pennsylvania: *U. S. Geol. Survey*, Bull. **136**, p. 41, 1896.

[25] Liebisch, Th., Mineralogisch-petrographische Mittheilungen aus dem Berliner mineralogischen Museum: *Zeitschr. d. Deutschen geol. Gesellschaft*, vol. **29**, pp. 710–734, 1877.

[26] Hawarth, E., A contribution to the Archean Geology of Missouri: *Am. Geol.*, vol. **1**, pp. 365–367, 1888.

[27] Lacroix, A., Mineralogie de la France, vol. **1**, p. 155, 1893.

[28] Rogers, A. F., *loc. cit.*

[29] Lausen, Carl, *loc. cit.*

[30] Koto, B., Some Occurrences of Piedmontite in Japan: *Jour. Col. Sci., Imp. Univ. Tokyo*, vol. **1**, pt. 3, pp. 303–312, 1887.

——— On some occurrences of Piedmontite-Schist in Japan: *Quart. Jour. Geol. Soc.*, vol. **43**, pp. 474–480, 1887.

[31] Lacroix, A., Épidote Manganésifère (piémontite) de L'île de Groix: *Bull. Soc. Fr. de Min.*, vol. **11**, p. 148, 1888.

[32*] Harada, T., Die Japanischen Inseln, Erste Lief., *Berlin*, **1890**, p. 75.

Finally, the mineral has been noted as a detrital constituent in sediments near Lost Hills, California.[33]

Besides the occurrences mentioned above, Williams, in his paper, previously referred to, mentions piedmontite in the porphyries and felsites of the Boston Basin, and from "the Archean area of Georgia near Tennessee." It is likely that many localities in which this mineral occurs in small amounts have not been reported, but from those on record, it can be seen that the piedmontite is a mineral of wide-spread occurrence, and that it develops in quite a number of geologic situations, usually in minor amounts, but occasionally in such abundance as to be an important rock constituent, as, for example, in some crystalline schists of Japan.

ACKNOWLEDGMENT

The writer wishes to express his thanks to Professors A. C. Gill and H. Ries, for helpful suggestions concerning the preparation of the manuscript.

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[33] Reed, R. D., and Bailey, J. P., *loc. cit.*

NOTES AND NEWS

AN OCCURRENCE OF NATIVE SULPHUR IN CENTRE CO., PA.

R. R. ROSENKRANS, *Pennsylvania State College.*

Of considerable scientific interest, but of no economic importance, is the occurrence of a small deposit of native sulphur in Centre County, Pennsylvania. Native sulphur has previously been reported from but three counties of this state.[1] The deposit was noted while the writer was examining an abandoned quarry located four miles northwest of State College.

The quarry is located in limestones of middle Chazy age, the beds of which show an almost vertical dip as they lie on the northwest limb of the Nittany anticline. Fractures developed at the time of folding have been filled with calcite which, at this locality, frequently carries native sulphur. Good crystals of the sulphur are not found, the material being massive, of high purity, and intimately associated with the calcite. Bands of sulphur, ranging from two to four millimeters in width and up to twenty centimeters in length, are seen. In all cases calcite separates these bands from the containing rock which is a pronounced stinkstone.

The sulphur is looked upon as resulting from the incomplete oxidation of hydrogen sulphide carried by ground waters and derived from organic matter in the impure containing rock. No associated gypsum has been found.

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[1] S. G. Gordon, The Mineralogy of Pennsylvania: *Special Publication of Acad. Nat. Sci. of Phila.*, No. **1**, 1922.

A Correction

In the article "An Arizona Gold Nugget of Unusual Size" written by Robt. E. S. Heinemann and published in the *American Mineralogist* for June 1931, a correction is necessary. Evidence has come to light that John B. Earheart did not find the nugget, but purchased it from a prospector, Wm. (Mormon Bill) Johnson of Phoenix, who found the nugget on the claim of Henry Schoonover which is three miles east of Octave in the Weaver district. Mr. Heinemann has asked that the following letter received at the Arizona Bureau of Mines be published in the Journal.

Octave, Arizona,
Feb. 4th, 1932.

Dean G. M. Butler,
Tucson, Arizona.

DEAR SIR:

"To correct a mistake, and give credit where credit is due, permit me to inform you regarding the true history of the large nugget which is now in your possession and which came from the Weaver District, but not from Rich Hill, nor within three miles of it. This nugget was found on the claim of one Henry Schoonover, who lives about three miles east of Octave. The finder, Wm. (Mormon Bill) Johnson, of Phoenix, was out hunting rabbits, and found the nugget on top of an old dry wash tailing pile. It had evidently run over the screen, and was not noticed. Johnson came to my house and asked me to go to Phoenix with him and sell the nugget. We drove to Wickenburg, and showed it to Ed. Hill, who owns Hill's Garage. From there we drove to a filling station about seven miles east of Wickenburg, and at the station we met State Senator Al Favour, who tried to buy the nugget from Johnson. He did not sell it to the Senator. Then we proceeded to Phoenix. I separated from Johnson in Phoenix, and while he was away from me he sold it to John B. Earheart, who was conducting a stock selling campaign on a lot of worked-out ground on Weaver Creek.

"The present address of Earheart is Florence, State Penitentiary. And when he has served his sentence of from seven to ten years for confessed bigamy, he will probably have to explain something about salted sample pans, and stock selling thereon.

"Before Earheart landed in jail, the big nugget was used extensively as a sample of the nuggets that were supposed to come out of the worked out claims. If you care to take the trouble to look up the old files of the Phoenix Republican, you will find an account of the finding of the nugget, and our bringing it to the office of the newspaper. It was only today that I read the Pamphlet concerning the nugget. And it certainly riled me to find the name of a crook listed as the finder, especially as I knew that he bought it from Bill Johnson. He paid Johnson $175.00 for the nugget.

"I take no credit for myself in the transaction, as I only acted as guard to Johnson, who was afraid someone would try to steal the nugget between here and Phoenix. . . ."

Very sincerely yours,
FRANK J. GILLICK

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, March 3, 1932

A stated meeting of the society was held on the above date with the president, Dr. Cajori, presiding. Thirty-four members and twenty-three visitors were present.

Dr. Frank L. Hess of the U. S. Bureau of Mines addressed the society on "Pegmatites," illustrating his remarks with specimens and lantern slides. He considers pegmatites to be a general name for rocks with coarsely and unevenly crystallized and segregated minerals in dikes, veins or metamorphic masses, formed from aqueous solutions, from a freezing magma, or from their reactions with previously existing minerals. Features of a number of pegmatite deposits were described. A rising vote of thanks was tendered to Dr. Hess.

Messrs. Biernbaum and Arndt reported that the dumps of Wood's Chrome mine were being removed. Mr. Leonard Morgan exhibited chalcedony from Buckmanville. Mr. Wolf described brownish uraninite crystals from Easton.

W. H. Flack, *Secretary*

MINERALOGICAL SOCIETY OF SOUTHERN CALIFORNIA

The tenth meeting of the Mineralogical Society of Southern California was held in the Lecture Hall of the Pasadena Public Library on Monday, April 11, 1932, at 7:30 P.M. Dr. Fritz Zwicky, associate professor of theoretical physics at the California Institute of Technology, spoke on the subject "The Problem of the Solid State."

E. Van Amringe, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

Mineralogical Society, *March 15.*—Sir John S. Flett, President, in the chair.

Mr. F. A. Bannister: *The distinction of pyrite from marcasite in nodular growths.* X-ray single crystal and powder photographs show that nodules from the Chalk in the South of England are pyrite. Examination of polished sections of a number of these nodules by reflected polarised light confirms this work; in no case of nodular pyrite yet examined is there evidence of an intimate intergrowth of marcasite and pyrite. Both methods have also been applied to the study of nodules from other localities including the true marcasite nodules from Wisconsin, U.S.A., and pyrite nodules in shales. Nodular pyrite is far more common than was formerly supposed whereas nodular marcasite is comparatively rare.

Dr. L. Hawkes and Dr. H. F. Harwood: *On the changed composition of an anorthoclase bearing rock-glass.* The vitreous contact facies of a felsite dyke contains anorthoclase insets which cannot have grown in a liquid represented by the glass. The glass, which shows no outward sign of alteration and exhibits strain birefringence, has taken up soda and water and lost potash and silica. Glasses are more liable to metasomatic change than crystalline rocks.

Dr. A. E. Mourant: *The spherulitic rhyolites of Jersey.* The spherulites present a variety of structures. These are described and their origin is discussed, and particular attention is paid to rhythmic growth of which there are good examples in some of the spherulites.

Dr. Frederick Walker: *An albitite from Ve Skerries, Shetland Isles.* A specimen collected from this inaccessible group of rocks proves to consist of albite 90 percent, chlorite (replacing biotite?) 2 percent, quartz 2 percent, with accessory titaniferous magnetite and apatite. Texture granitoid. Specific gravity 2·64. Chemical analysis compares closely with those of albitites from the Ural Mountains, and from the Assynt district, Sutherland.

NEW MINERAL NAMES

Arsenoklasite

G. Aminoff: Arsenoklasite, a new arsenate. *Kungl. Svenska Vetenskapsakdemiens Handl. Tidskrift*, Band **9,** 1931, No. 5.

Name: Derived from the Greek words for arsenic and the verb to split or break.

Chemical Properties: A hydrous manganese arsenate. Formula: 5 $RO \cdot As_2O_5$. 2 H_2O or $Mn_3(AsO_4)_2$. 2 $Mn(OH)_2$. Analysis by R. Blix: As_2O_5 36.96; MnO 55.01; MgO 0.87; FeO trace; BaO 0.11; CaO 0.57; H_2O 5.86; H_2O 110°– 0.04. Total 99.42.

Crystallographic Properties: Does not occur in crystals. Laue Photographs taken perpendicular to the cleavage shows the mineral has orthorhombic symmetry.

Physical and Optical Properties: Color red, cleavage (010) very good, hardness 5–6. Specific Gravity 4.16. $\alpha = 1.808$, $\beta = 1.810$, $\gamma = 1.816$ (Na), V (Na) = 26°43′.

Occurrence: Occurs with sarkinite in fissures in hausmannite, impregnated dolomite; similar to sarkinite but may be distinguished by its more pronounced cleavage.

Discussion: Chemically arsenoklasite occupies a position between sarkinite and allactite.

$Mn_3(AsO_4)_2 \cdot Mn(OH)_2$	sarkinite
$Mn_3(AsO_4)_2 \cdot 2Mn(OH)_2$	arsenoklasite
$Mn_3(AsO_4)_2 \cdot 3Mn(OH)_2$	unknown
$Mn_3(AsO_4)_2 \cdot 4Mn(OH)_2$	allactite

There are three copper minerals whose formula is analogous to arsenoklasite. These are dihydrite, erinite, and turanite.

E. P. Henderson

Ardealite

J. Schadler: Ardealite, ein neues Mineral, $CaHPO_4 \cdot CaSO_4 \cdot 4H_2O$. (Ardealite, a new Mineral, $CaHPO_4 \cdot CaSO_4 \cdot 4H_2O$). *Centr. Min. Geol.*, Abt. **A,** No. 2, pp. 40–41, 1932. Also F. Halla: *Zl. Krys.*, **80,** 1931, 349–352.

Name: From the locality Siebenbiergen (=Ardeal).

Chemical Properties: A hydrous phosphate and sulfate of calcium: $CaHPO_4$ $CaSO_4 \cdot 4H_2O$. Analysis: CaO 31.61, SO_3 21.25, P_2O_5 21.85, H_2O+ 25.14, Insol. 0.39. Sum 100.24.

Physical and Optical Properties: Color light yellow. Fine powdery. Sp. Gr. 2.300.

Occurrence: Found in phosphate earth deposits in the caves of Cioclovina, Roumania, with gypsum and brushite. Results from the action of ground solutions on limestone blocks.

Discussion: *X*-ray examination indicates that ardealite is a definite compound and not a mixture of gypsum and brushite.

W. F. Foshag

Rosickyite

J. Sekanina: Rosickyit, die natürliche γ-Schwefelmodifikation. (Rosickyite, the natural γ-sulphur modification). *Zeit. Kryst.*, **80,** 174–189, 1931.

Name: In honor of V. Rosicky, Director of the Mineralogical and Petrographical Institute of Masaryk University, Brno.

Chemical Properties: Sulfur, S. Soluble in benzol, methylene iodide and carbon bisulfide. Alters in time to α-sulfur.

Crystallographic Properties: Monoclinic, habit equidimensional to platy to acicular. Forms: (010), (210), (111) common; $(\bar{1}11)$, (012) less common; (001), (100), (110), (230), (011), (101), $(\bar{1}01)$, (121), $(\bar{3}21)$ rare. $a=1.0606$, $c=0.7094$, $\beta=91°48'$. $e'=0.0314$, $p_0'=0.6689$, $q_0'=0.7091$.

Physical and Optical Properties: Color, colorless to pale yellow with greenish cast, without pleochroism. Luster adamantine. Hd. low. Cleavage not observed, $G. < 2.075$. Biaxial negative. 2V large, axial plane parallel to (010). $X \wedge c = 1\frac{1}{4}°$. n high. Birefringence high. Twinning on (101) observed, the twinning lamellae parallel to the edge (010): (111) with symmetrical extinction of 23°.

Occurrence: At Havírna near Letovice, Mähren, Czechoslovakia, in the center of hollow limonite nodules. These nodules, about walnut size, are found in a thin stratum of clay. The crystals are mostly less than 0.5 mm. in size.

W.F.F.

Wischnewite

D. S. Beljankin: Zur Mineralogie und Chemie eines Feldspatvertreters aus der "Wischnewy Gory" (Ural). (On the Mineralogy and Chemistry of a Feldspathoid from Wischnewy Gory, Urals). *Centr. Mineral. Geol.*, Abt. A, **1931**, pp. 190–196. Also A. N. Zawaritzky: *Mem. Soc. Russ. Miner.*, **58**, 1929, pp. 201–207.

Name: From the locality Wischnewy Gory, Urals.

Chemical Properties: A sulfatic cancrinite, $3Na_2Al_2Si_2O_8 \cdot Na_2SO_4 \cdot 3H_2O$. Analysis (by E. W. Knipowitsch): SiO_2 34.53; TiO_2 0.10; Al_2O_3 26.09; Fe_2O_3 0.56; FeO 0.11; MnO 0.09; MgO 0.09; CaO 1.48; Na_2O 16.51; K_2O 5.11; Cl_2 0.09; SO_3 5.02; CO_2 0.26; H_2O+ 5.35; H_2O- 1.36. Total 100.02.

Physical and Optical Properties: Color pale blue, cleavage prismatic.

Under the microscope, colorless. Uniaxial negative. $n=$ (Beljankin), 1.492 $-$1.493, 1.489 (Zawaritzky). Birefringence 0.0007. Cleavage hexagonal. Sometimes shows fine lattice type of twinning.

Occurrence: Found at Wischnewy Gory (Vischnevy Mts.), especially in Kurotshkin Valley and the Ilmen Mts. in miaskite pegmatites as an alteration and replacement of nephelite, associated with natrolite and cancrinite (Ilmen Mts.) or scolescite and hydrargillite (Vishnevy Mts.).

Discussion: Its relation to the cancrinite group is shown in the following table:

Davynite	$3Na_2Al_2Al_2Si_2O_8 \cdot 2NaCl$.
Wischnewite	$3Na_2Al_2Si_2O_8 \cdot Na_2SO_4 \cdot 3H_2O$.
Cancrinite	$3Na_2Al_2Si_2O_8 \cdot 2CaCO_3 \cdot 3H_2O$.

W.F.F.